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THE BAR-LOCK TYPEWRITER.

[*Being the report of the Institute by its Committee on Science and the Arts on Improvements in Typewriting Machines invented by Charles Spiro.*]

The Committee on Science and the Arts received from the inventor, Mr. Charles Spiro, the accompanying letter setting forth his claims to merit in the design, construction and operative features of the bar-lock typewriter. As will be perceived from the report which follows, the committee charged with the investigation of the subject, has considered and passed judgment on these claims *seriatim:*

NEW YORK, June 2, 1893.

To the Committee on Science and the Arts of the Franklin Institute, Philadelphia, Pa.:

GENTLEMEN:—In bringing my invention of the bar-lock typewriter before you for your consideration, I desire to state as briefly and concisely as possible the advantages possessed by this machine. My idea is that the best typewriter is that one which enables the operator to produce the most work of the finest quality, in the shortest time, with the least physical effort.

FIG. 1.

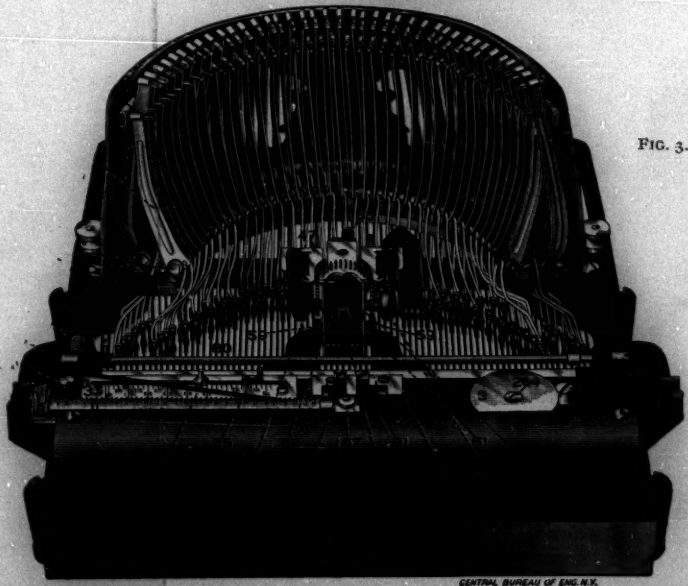

FIG. 3.

It has, therefore, been my endeavor to accomplish these results in as simple a manner as possible, and at the same time to make its movements, where possible, automatic.

Visible Writing.—With this object in view, the machine was so designed that the writing should be in full sight of the operator, as if he or she were using a pen, thus obviating the necessity of wasting time in lifting the paper carriage or pulling forward the platen to examine the work done. Having gained this advantage, it becomes very simple to make alterations or to execute tabular work thereon. Visible typewriting increases the output of the machine, as three words can be written in the space of time required to lift the paper carriage, and on an average an expert operator will lift the paper carriage once in every five lines.

Automatic Line Spacing.—The next improvement was to make one movement suffice for returning the paper carriage to the right and turning forward the paper, ready for a fresh line. To this must be added the light paper carriage, allowing of a very rapid movement. On a careful test it has been found that a new line is started every thirteen words. On the majority of typewriters, the action of starting a new line occupies a space of time equal to *four* words of writing On the bar-lock the time occupied is equal to that of writing *two* words. The operator is saved the one entire action.

Automatic Ribbon Reversing Gear—On all typewriters using ink ribbons, it is necessary when the ribbon has been fully unwound from the spool for the operator to reverse the driving gear. On the bar-lock, when the ribbon has reached either end, it automatically reverses, thus saving the operator any effort in this direction, and also avoiding the fear of a letter being spoiled through the operator forgetting to reverse the ink ribbon, which is a matter of common occurrence on other typewriters, as no warning is given by the machine that the end of the ribbon has been reached.

Automatic Platen Backward Release.—The operator does not have to lift up the driving pawl used in driving the paper forward, when it is necessary to turn the paper back, as on other machines. The backward movement of the platen of the bar-lock throws the platen automatically out of mesh with the ratchet wheel.

Automatic Keyboard Lock.—Many operators are troubled through not noticing the ringing of the bell, and thus spoil the appearance of their work by writing after the carriage has reached the end of the line. By this device the operator can cause the keyboard to be locked at any desired number of letters after the ringing of the bell, thus preventing the keys being depressed to print. This lock is so designed that the keys are not locked rigidly, but are allowed to descend a short distance, avoiding any shock to the operator's fingers. By the simple turning of a screw this device can be thrown out of gear, if the operator prefers the machine without it.

Automatic Double Bell Alarm.—This is of use where an operator is writing two columns of any matter, and wishes an alarm at both columns. It can also be used at the end of the line for a double bell alarm, in the event of the first bell being unnoticed.

Device for Writing on Ruled Lines.—It is very often necessary to fill in a date or numerals on a given line on the sheet of paper. This necessitates on other typewriters, considerable waste of time in pulling the paper by the

hand until it reaches the desired spot. By my invention, it is only necessary to depress a small lever, and the paper platen can then be turned in any direction and to any position. Thus an interlineation can be made, and invoices can be made out on ordinary ruled paper, or blank forms filled in, without loss of time.

Margin Devices.—I would also draw attention to the simplicity and rigidity with which the left or right hand margin can be set at any desired spot.

FIG. 2.

Automatic Margin Release.—The margin stop on this machine is so contrived that upon the depression of a key the margin set for is instantly released, enabling the operator to insert the initials *Q* and *A*, the names of witnesses, etc., or to write marginal notes, at the left of the marginal ruling originally set for. When the marginal note is completed, the stop automatically recovers its first setting.

Typebar Lock.—The great problem of all manufacturers of typewriters is to devise a typebar-bearing or a lock which will insure the printing of the type in

alignment after considerable wear. There have been many attempts to make a lock for the typebars, some being designed to guide the typebars by means of a groove, and others making use of a locking aperture over the printing point to receive the type. The disadvantage of both these methods was the weakening of the stroke of the typebar, caused by the friction, and also that the alignment depended on the lock *solely* and the type was literally *forced* into the lock. With the bar-lock, the lock is simply to *maintain* the alignment and is not to *force* the alignment; that is, each typebar is of such a character that it has a joint sufficiently rigid to insure the letters printing upon a straight line when the machine is new; but instead of depending upon this joint after the machine is old, as is the case in the majority of typewriters, the lock is placed near the printing point, which receives the typebar at the moment of contact with the paper and prevents any side play. This lock consists simply of a semi-circle of conical phosphor-bronze pins about three-sixteenths of an inch in height. The only friction therefore is the friction of two small pins against a flat bar, and this does not occur until after the bar has attained its fullest momentum, and hence does not in any way weaken the stroke for manifolding or retard the quick recoil of the typebar from the platen.

Typebar Hangers.—It being my object to make the most durable typewriter possible, I have placed not only a lock at the printing point, but have made my typebar bearings or hangers adjustable. To do this, I have designed an adjustable ball and cup bearing. My claims of superiority, as compared with the ordinary cone bearings, are that the ball and cups have a coincidence of bearing surface at every angle, so that when the adjusting screws draw the forks of the hanger together, it makes no difference whether the forks are parallel or not; hence the taking up of the hanger for wear does not affect the typebar.

Other Features.—In addition to the leading features peculiar to the bar-lock which I have enumerated, I have also included in the machine many other advantages, some of which are possessed by other typewriters, though in a different form.

Among these, I may state that the paper platens are *instantly* removable and interchangeable, so that an extra hard platen may be inserted where a large number of manifold copies are required.

The ink ribbon spools are also interchangeable and reversible, so that the whole width of the ribbon can be utilized.

For obtaining a uniform margin on many sheets of paper there is an adjustable margin guide, and by depressing a small lever flimsy paper can instantly be withdrawn from the carriage without fear of injury.

The carriage release for moving the carriage to the left is instantaneous, and the carriage stops "dead" and does not jump several teeth as on other machines.

I have also a special feed for printing envelopes quickly without rolling them around the platen.

My key-levers are of steel and in one piece. The typebars are of resilient steel, and if two keys are accidentally depressed at one time, neither letter prints and the typebars are uninjured.

The arrangement of the typebars is such that the whole of the type can be cleaned in five seconds. I use a standard keyboard of *seventy-eight* keys, arranged in duplicate of capital and small letters. The touch of the machine is light and easy, and the action more nearly noiseless than ever before attained. * * * * * * * * * *

I am, gentlemen, Yours respectfully,

CHARLES SPIRO.

REPORT.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 30, 1893.

The Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the "Bar-lock typewriter," finds as follows:

This machine is fully described and illustrated in the following letters-patent, copies of which are annexed, viz:

No. 322,495 June 21, 1885, granted to C. Spiro.
No. 322,989, July 28, 1885, granted to C. Spiro.
No. 331,337, December 1, 1885, granted to C. Spiro.
No. 339,078, March 30, 1886, granted to C. Spiro.
No. 344,143, June 22, 1886, granted to C. Spiro.
No. 352,160, November 9, 1886, granted to C. Spiro.
No. 355,418, January 4, 1887, granted to C. Spiro.
No. 395,799, January 8, 1889, granted to C. Spiro.
No. 400,265, March 26, 1889, granted to C. Spiro.
No. 400,716, April 2, 1889, granted to C. Spiro.
No. 410,743, September 10, 1889, granted to C. Spiro.
No. 422,042, February 25, 1890, granted to C. Spiro.
No. 435,775, September 2, 1890, granted to C. Spiro.
No. 438,901, October 21, 1890, granted to C. Spiro.
No. 445,333, January 27, 1891, granted to C. Spiro.
No. 447,438, March 3, 1891, granted to C. Spiro.
No. 454,080, June 16, 1891, granted to C. Spiro.
No. 475,623, March 24, 1892, granted to C. Spiro.
No. 476,093, June 14, 1892, granted to C. Spiro.
No. 481,377, August 23, 1892, granted to C. Spiro.

It is a full keyboard typebar machine, with upright typebars printing on top of the platen in full view of the operator, arranged in two decks so that the whole seventy-eight typebars occupy only about one-third of a circle.

The details of construction of the machine will be

brought out in the discussion of the special "points of merit" claimed for it, in which it will be stated whether, and to what extent the same or similar "points of merit" exist in other machines within the knowledge of the committee conducting the investigation; the statement that any of these is found in one or more other machines not implying that the same other machine is always meant, as the contrary is the case.

(1) *Visible Writing.*—The writing in this machine is entirely visible for the last two lines of the work, including the last letter struck. Other machines within the knowledge of the committee have this point with equal perfection, and some others more or less proximately.

(2) *Automatic Line Spacing*, or the partial revolution of the platen for a new line by the act of returning it for the beginning of a line. This point is found in other machines.

(3) *Automatic Ribbon Reversing Gear.*—When the ribbon has run to its end, it is automatically reversed, so that the operator is not called upon to pay any attention to its position, and is not liable to continue writing after the ribbon feed has ceased, wasting time and spoiling work.

This point is found in no other machine and is of importance. This, however, gives no advantage over those which print directly from the type without the intervention of the ribbon.

(4) *Automatic Platen Backward Release.*—The platen is turned backward by simply turning the knob on its end without other action. This point, which is often very convenient, is found on no other machine.

(5) *Automatic Keyboard Lock.*—At any given point at which it is desired to end the line of writing the keys may be so locked that the types will not print, not rigidly locked, but so that the typebar will move down part way, without shock to the finger of the operator, or to the machine. The feature of locking the key at a given point of the line is found in one other machine, but the allowance of partial movement, without writing, in no other.

(6) *Automatic Double Bell Alarm.*—This machine has two bell alarms, one of which can be set at any point on the line,

and the other near the end, so that two alarms can be given for two separate columns on the same page, or a double alarm at the end of the line, so as to insure the attention of the operator. This point is found in no other machine, and may occasionally be of advantage.

(7) *Device for Writing on Ruled Lines.*—The platen feed may be thrown out of gear by a single movement of a lever, and the platen can be moved to write on previously ruled lines. This point is found on other machines.

(8) *Margin Devices.*—For setting a margin on either end or both ends of the line. This point is found in other machines.

(9) *Automatic Margin Release.*—By the touch of a key the left hand margin stop may be thrown out of action, enabling the extension of the line to the side of the page or the making of marginal notes. This point, as far as relates to the actual doing of the thing, is found in two other machines, but in none with the facility with which it is done in this machine.

(10) *Typebar Lock.*—The typebar at the point of making its stroke, is locked in position so that the proper position of the letter on the line is assured. This point is found in other machines.

(11) *Typebar Hangers.*—The typebars move in adjustable ball bearings, in which wear can be accurately taken up. This point is not found in any other machine.

These are the principal features of special excellence over other machines claimed for this one, and in addition, the inventor names several other "advantages" which, as he correctly states, are "possessed by other typewriters, though in different form," and which are, therefore, not necessary to be enumerated here.

The relative advantages of the partial keyboard, with shift or shifts, and the full keyboard, is a matter depending upon the personal aptitude of the operator, and is a subject upon which we do not feel called upon to express an opinion; but, disregarding this question, and comparing this machine with other writing machines, we find that although some machines possess capabilities not possessed by this

one, it presents an exceedingly advantageous combination of them and has some points of merit peculiar to itself. It has a light, elastic touch and a very positive movement of its platen escapement. It has a long typebar, and is, therefore, a good manifolder.

The Institute, therefore, recommends the award of the John Scott Legacy Premium and Medal, to Charles Spiro, of New York, for his "Improvement in Typewriters."

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, December 6, 1893.

JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
H. R. HEYL,
Chairman of the Committee on Science and the Arts.

Award confirmed by the Board of Directors of City Trusts, 1894.

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ON GAS BURNERS, GAS PRESSURE REGULATORS AND GOVERNOR BURNERS, GAS GLOBES AND GLOBE HOLDERS, AND GAS FIXTURES.

BY WM. PAUL GERHARD, C.E.,
Consulting Engineer for Sanitary Works, New York City.

In the following pages I propose to discuss the chief means for obtaining a good and satisfactory illumination by gaslight. It is to be assumed:

(*a*) That the gas supplied to the consumer is properly purified at the gas works, and that in quality it is of the requisite and sufficient candle-power:

(*b*) That the gas piping in the building has been done in a first-class manner; that pipes and fittings of proper material and of ample size have been used; that these pipes and fittings have been put together in a workmanlike manner and are tightly jointed; that the distributing pipes have been properly run, with sufficient grade and with good fastenings and supports; that all gas outlets have been securely

strapped; and that the piping has stood a severe pressure test, and has no leaks or imperfections:

(*c*) That the gas company has run a service of ample size into the premises, and has set a gas meter of sufficient capacity to supply all lights or burners likely to be kept burning at one time.

Under such conditions the factors upon which the illumination depends are the gas burners, the pressure regulators, the globes and globe holders, and the gas fixtures.

Briefly stated, the essential steps which gas consumers desiring good illumination should take, are:

(1) To select and use the best quality of gas burners, for these will not only give a better light, but they will burn less gas in proportion to the candle-power developed than poor burners, or, to put it in other words, they will produce a higher candle-power per unit of gas consumed.

(2) To regulate the pressure with which the gas issues at the burner, which may be accomplished either by the use of gas pressure regulators on the main house pipes for gas, or by using volumetric or governor burners at the gas fixtures.

(3) To regulate the air supply to the flame which is accomplished by the use of suitably shaped and suitably placed gas globes, and in the case of argand burners by the use of well proportioned glass chimneys.

(4) By selecting well designed and well constructed gas fixtures and judiciously placing same in the apartments to be lighted.

According to an elaborate report made by the London Gas Referees in 1870, a serious waste of gas occurs, owing to the great number of bad burners in general use. Consumers may, by using good instead of poor burners, obtain from thirty to fifty per cent. more light without any increase in the gas bills. From this it is evident that gas may be used wastefully or economically, this depending largely on the selection of the burners. Burners suitable for ordinary coal gas are not adapted for gas of high candle-power, and *vice versa*. Unfortunately, the proper methods of burning gas are little understood, not so

much owing to want of popular information on the subject, as on account of the general indifference of the gas consuming public as well as of the gas companies. Gas consumers are, as a rule, very slow in the adoption of progressive methods or appliances in domestic gas lighting, and the gas companies, with a few commendable exceptions, have not in the past made the slightest efforts in the interest of the consumers, by explaining in a lucid manner the problem of how to burn gas economically, and how a maximum efficiency of light, combined with perfect and complete combustion, may be obtained from the burning of a cubic foot of gas.

Much remains to be accomplished in this direction, many widely existing fallacies regarding gas lighting have to be fought and removed, and in their place a correct knowledge of the principles of gas illumination should be disseminated. In by far too many cases the existing conditions, such as too small pipes, meters of insufficient capacity, excess of pressure, bad burners, ill-shaped globes, cumbersome globe holders and defective gas fixtures, preclude any chances of obtaining a successful illumination.

I cannot here go into a consideration of the nature of the gas flame or into the theory of combustion, and will simply state as a general axiom that gas *should be burnt at a low pressure*. The most favorable pressure varies slightly with the quality, candle-power and specific gravity of the manufactured gas, but may be taken on an average as five-tenths inches of water pressure at the burner. An excessive high pressure of gas has a tendency to reduce the illuminating power of the gas flame and causes the roaring or singing of a flame, the flickering of the light, the cracking of glass globes and a waste of gas.

On the other hand, if the pressure is too low, the flame is apt to smoke, becomes dull and reddish in appearance and vitiates the air.

I.—GAS BURNERS.

A gas burner has been defined as the point at which illuminating gas issues from the service pipe to be ignited

for the purpose of giving light (or in some cases heat). All burners are composed of two parts, the body and the tip of the burner.

Early in the history of gas lighting we find the energies of able inventors devoted to the improvement of the originally crude devices serving as gas burners, and it is both interesting and instructive to follow the gradual development of the better class of burners. A fresh impetus was given to the gas burner industry by the introduction of the electric light. This compelled gas companies to devote attention to the available better gas appliances for street illumination, and also caused consumers to make inquiries about the details of properly constructed gas burners for interior lighting. At the present day the simplest as well as the most scientifically and accurately constructed gas burners are available, and new improvements are constantly being made.

Broadly speaking, we may distinguish between the following *types of gas burners*, viz :

(*a*) Single jet burners.
(*b*) Flat-flame burners.
(*c*) Round-flame burners.
(*d*) Multiple burners.
(*e*) Regenerative burners.
(*f*) Incandescent burners.

Of all gas burners the *single jet burner* is the simplest and crudest, consisting of a plain body and tip generally combined, having only one small round aperture for gas. These burners are used only to a limited extent where a very small flame is required, and hence we may dismiss them with these few words.

The second and third types of burners, viz., the flat-flame and the round-flame burners, are those with which we are chiefly concerned in dwelling house illumination, and of these two types again, the bulk of burners used belongs to the flat-flame type.

All *flat-flame burners*, as the name implies, spread their flame in a thin, broad sheet. It is usual to distinguish two

kinds of flat-flame burners, viz., the bats-wing, or slit-union burner, and the union-jet, or fish-tail burner.

The batswing burner has a hemispherical tip, with a narrow vertical slit, from which the gas issues in a thin and broad sheet, whereas the union-jet, originally invented by James Milne, of Edinburgh, consists of a flat and sometimes of a slightly depressed, or concave tip, with two small holes drilled under a certain angle to each other, from which two jets of equal size issue, and impinging upon one another produce a flat flame.

Flat-flame burners do not require the use of a chimney to prevent the smoking of the flame, but as a rule, the gas flame is sheltered against draught by surrounding it with a glass globe.

As originally constructed the two burners produced flames widely differing in character, the batswing burner giving a flame of great width and little height, while the fish-tail burner produced a flame considerably narrower and longer.

On account of its great width, the flame of an ordinary batswing burner is easily affected by even slight currents of air, which cause the flame to smoke, and the protection which a glass globe affords to the flame cannot be so readily applied to the common batswing burner, because the slightest lateral deviation of the broad flame often causes the cracking of the glass globe. This is one reason why ordinary union-jet burners are so commonly used on gas fixtures with glass globes, although the batswing burner is slightly preferable, as regards development of light.

An early step in the improvement of flat-flame burners consisted in simple and crude devices intended to reduce the velocity with which gas issues at the burner orifice, owing to the gas pressure, experiments having established the fact that a greater degree of illumination could be obtained by burning gas at a low pressure. These devices consisted in introducing some mechanical obstruction, such as wire gauze, or cotton, or wool, or a mica disc, or a regulating screw, into the body of the burner. Owing to the fact that coal gas is not always well purified, all devices

which serve to constrict the lower part of the burner, are very liable to stop up with tarry matters carried in suspension in the gas, which become condensed and are deposited in the wire gauze or in the wool. After some use, such "check burners," as they are sometimes called, generally become unfit, or at least produce a very ragged and uneven flame, owing to the material in the body of the burner becoming more obstructed in some parts than in others.

The first valuable improvement in gas burners consisted in the choice of a more suitable material for the tip or head of the burner. The old burners, which are, unfortunately, still much in use at the present day, were usually made entirely in one piece, either of iron or of brass. Movable tips were introduced later on, and were inserted into the metal body of the burner, but at first these tips were still made of iron. This material is objectionable for two reasons, viz: first, the burner orifices in union-jet and in batswing burners become rapidly choked by the corrosion of the metal. Such obstructions by rust may, it is true, be removed from time to time with burner cleaners, sold in hardware stores or obtainable from the gas companies, those for union-jet burners being in shape of a small awl, while those for slit burners consist of thin strips of sheet brass or steel, fastened to a suitable handle. The average householder rarely bothers himself with such matters; but even where these burner cleaners are used, the inevitable result of their too frequent or careless use will be that the burners quickly become injured or destroyed. The nickel plating of the iron burner tips obviates to some extent the corrosion of the burner orifice, and quite recently a non-corrosive metal gas tip has been put on the market, for which the advantage is claimed that it does not chip or crack, as lava tips sometimes do.

A second and more important objection against brass or iron burner tips is that metal being a good conductor, abstracts much heat from the burner tip, and thereby reduces the temperature of the flame, causing some loss in the degree of illumination.

Therefore, a great step forward was made by the intro-

duction of non-metallic, non-corrosive and non-conducting substances for burner tips. The material most commonly used is lava, but this is brittle and cracks easily, and various gas burner manufacturers employ other materials, such as porcelain, or steatite (a sort of soapstone of very fine grain which burnt in a kiln becomes hard and incorrodible, and is easily polished) or "adamas," a compound artificial material of a mixture of various earths or minerals, or some sort of "enamel."

Sugg's burners have steatite tips, Bray's burners enamel, and Leoni's burners adamas tips; and all modern improved flat-flame and round-flame burners have tips made of one or the other of these materials, which are practically everlasting and not susceptible of oxidation.

Further improvements made relate to the shape of the tip and of the body of the burner. In some gas burners, for instance, the body is suitably enlarged to form a sort of expansion chamber wherein the velocity of gas as it issues from the pipe is, to some extent, checked.

The batswing burner was improved by making the interior of the top of the burner hollow. The slit thereby becomes of equal depth throughout. Sugg also improved the batswing burner by cutting the slit with a circular saw, which has a favorable effect upon the shape of the flame. The advantage is thereby gained that gas issues more uniformly at all the points of the tip, and the shape of the flame thereby becomes improved, becoming less broad and somewhat taller.

A further improvement of the batswing burner was made by Wm. Sugg, who applied a rim-like projection to the outside of the burner below the slit, a so-called "table-top," the object of which was to check the rush of the outer air in the immediate vicinity of the flame. Thus the flame is better protected from draughts, the shape of the flame is more evenly preserved, and all smoking is prevented.

Manufacturers of union-jet burners, in turn, were not slow in applying improvements to their type of burner. Some introduced into the body of the burner layers of muslin to check the flow of gas, others inserted plugs or wash-

ers of enamel, perforated with small apertures for the passage of gas. These apertures can be adjusted to various pressures, and the ultimate object in view is to cause the gas to issue at the burner tip at the lowest pressure consistent with proper illumination. The result is that the height of the gas flame, which in the common fish-tail or union-jet burner is excessive, becomes considerably reduced and the roaring and flickering of the light is prevented. A similar result was obtained by making the burner top slightly hollow, and the angle at which the two streams of gas meet, more obtuse.

By all these improvements the two at first quite different flames of the batswing or slit burner, and of the union-jet or fish-tail burner have been modified and gradually altered so much that in their modern most improved form the shapes of the flames of the two types, are *practically identical.*

Among the best improved flat-flame burners are those of Broenner, Leoni, Sugg, Bray and Silber. The Sugg improved hollow-top steatite slit burner, the Sugg circular slit table top steatite burner, the Bray enamel non-corrosive "regulator" fishtail and slit burners, and the Silber "Concordia" flat-flame burner, which has two small burner orifices separated by an intervening wedge-shaped piece of brass, are among the best ordinary flat-flame burners obtainable in the market. These burners are all of English make, except the Broenner burners, made in Frankfort-on-the-Main, Germany. Of the latter burner eleven numbers are made, consuming from one to eight cubic feet of gas per hour. They give a more uniform light with varying gas pressures, and if judiciously selected and fitted with the "Cornelian" globes with large bottom and top opening and a shadowless glass holder, as recommended by the manufacturers, they give a good light.

I have not learned of any efforts on the part of American gas fitting manufacturers to provide improved ordinary flat-flame burners, comparable at all in efficiency with those above named.

The mill burner with screw check, the "Empire" check

burner with inside adjustable screw cylinder with slot, the "Imperial" burner with wire gauze to check the flow of gas, the Gregory mica flap burner and the "Young America" burner with small brass diaphragm pierced by minute holes, are gas burners of American make, and being in the nature of check burners are somewhat better than the ordinary kind. I shall, however, have occasion further on, when speaking of governor burners, to mention some very excellent American flat-flame burners.

In a dwelling house of average size only a comparatively small number of burners are required, hence it will pay gas consumers to put on their fixtures the best burners, whatever their price may be. Improved gas burners are also much preferable from a sanitary point of view, because there is less contamination of the atmosphere in a house.

Regarding the size of the burners I would say, wherever a dim light only is required, as in halls, passage-ways and bathrooms, two or three foot burners, and for bedrooms three or four foot burners may be used, but for the gas fixtures in the principal rooms large burners, consuming from five to six cubic feet of gas per hour are much to be preferred, and it should be borne in mind that for bright illumination a few large burners—under low pressure—are preferable to a large number of small burners. Under all circumstances consumers should avoid making the mistake of procuring gas burners promiscuously from irresponsible agents or from peddlers and afterwards blaming the gas company for "poor light," or for exorbitant gas bills.

Before leaving the flat-flame burners, I ought to mention some *automatic safety* gas burners recently devised, the object of which is to automatically shut off the gas supply in case light is accidentally extinguished, or "blown out," or in case the gas key is inadvertently turned on. An American patented device of this kind has a wire protruding from the burner tip, and extending down to the bottom of the burner where it comes in contact with a small valve. While the burner is cold the valve is closed, cutting off the gas supply. When a light is applied to the burner the wire becomes heated, expands, lengthens and pushes the valve away from

its seat, thereby admitting the gas to the burner tip. As soon as the flame is extinguished, the wire by cooling contracts and again cuts off the gas. A similar safety regulator burner is patented by Jahn, and manufactured by Friedrich Lux, of Mannheim, Germany.

These burners would seem to be specially adapted for hotels and lodging houses where gas is often "blown out" by ignorant people, and they may prove successful in preventing suffocation, suicides, explosions and other accidents due to escaping gas.

I have devoted a great deal of space to the discussion of the ordinary flat-flame burners because, the Argand, regenerative and incandescent burners notwithstanding, they are still the consumer's favorite burners, and because the bulk of illuminating gas used for lighting purposes is at present burnt in batswing and fish-tail burners. Further mention of flat-flame burners will be made in the discussion of governor burners. I will now pass on to consider the round-flame, or so-called Argand, burners.

Argand or *round-flame burners* consist essentially of a hollow ring, connected with the gas tube and perforated on its upper surface with a series of fine holes from which the gas issues, forming an annular hollow round-flame. The Argand burner derives its name from its similarity with the Argand oil lamp, and like the latter always requires a glass chimney, properly proportioned in diameter and height, to induce a perfect combustion by increasing the air supply to the flame, and to lessen its susceptibility to side draughts. The Argand burner gives a higher candle-power per unit of gas consumed than flat-flame burners. The original burners of this type were not constructed on scientific principles, no provision having been made in them for regulating the air supply to the flame and—what is equally important—the pressure of gas, and hence these burners were liable to smoke.

We are indebted for important improvements in this direction to Mr. William Sugg, the well-known English manufacturer of improved gas-lighting appliances. In his improved Argand burner gas is delivered at a very low pres-

sure, the supply is distributed evenly throughout the entire ring of holes, the flame generated is of even and regular shape, the chimney, which is so essential to the round-flame burner, is properly proportioned in diameter and height, and the burner is made of "steatite" instead of, as formerly, of metal, which abstracts too much heat from the flame. The Sugg "London" Argand burner, with twenty-four holes, was selected by the London Gas Referees, in 1869, as the standard test burner for sixteen candle gas.

Further improvements were embodied in Sugg's "London" improved Argand governor burner, which develops a still better light from the gas consumed, and in which a regular and uniform supply of gas to the burner is insured by the use of either a steatite float or a leather diaphragm governor.

An equally excellent Argand burner, with automatic governor, is made by the Silber Light Company, of London, while of American round-flame burners I mention the "noiseless" Argand burner, made by the Gleason Manufacturing Company. All these burners are much improved by the addition of the volumetric gas governor which maintains a steady flow of gas and regulates the pressure. Of this apparatus I have occasion to speak hereafter.

The Siemens precision burner is an improved Argand burner, having a flat disc in the center of the flame, which causes same to bulge out and tends to a more perfect combustion with increased luminosity of the round-flame. This is similar in principle and construction to the metal button deflector placed over the air tube, as adopted in many of the modern improved central draft oil lamps.

Similar modifications of the Argand burner are the Grand gas lamp, the Niagara Argand burner, the Royal Argand, the Gordon-Mitchell high-power gas lamp, with inverted annular burner, forming a small regenerative Argand burner, and the Morey incandescent gas light burner.

In order to obtain increased illumination, *duplex* and *multiple* gas burners were invented. In the double, duplex, or "twin" flat-flame burner, two batswing or sometimes two

union-jet burners are placed together on the same body and set at a certain angle to each other, so that the two flames are made to combine. A somewhat greater amount of light is developed thereby than by using the two flames separately, but the light is no better than that obtained through a large single burner.

Multiple burners consist of several concentric rings of round burners, or else of a series of three, five or more flat flame burners arranged in such a manner that from whatever point they are looked at, a flat side of the flame is exposed. Bray's high-power street lamp burners belong to this class, as well as Sugg's "Walthamston" and "Taj" high-power lights. They have been gotten up and used to some extent to obtain a brighter street illumination, also for lighting stores and large halls. The street lanterns of this type are made storm-proof, so that the flame is not affected by the wind, and are provided with milk white glass at the top of the lantern for the purpose of reflecting the light downward. Multiple round-flame burners have been adopted to a limited extent in lighthouse and street illumination, such as the Wigham multiple burner and the Germania double and triple concentric Argand burners.

The "Shaw" reflector light is a regenerative multiple flat-flame burner, in which an attempt is made to superheat the gas before ignition. Halliday's "Clapton" lights are similar in principle, and in the United States similar lights largely used are the Gregory incandescent and the Gleason "Beacon" lights.

I will next consider the *high-power* or *regenerative gas burners*. In all burners of this type the high temperature due to the combustion in the gas flame is directly utilized to raise the temperature of the gas before ignition, or of the air supply before combustion, or of both, the result being an intensified and more perfect combustion, and a vastly increased illuminating power. All regenerative lamps produce a higher efficiency of candle-power per cubic foot of gas consumed than is secured by ordinary burners, the burners are economical in gas consumption, and the light produced is intense and steady.

One of the first regenerative burners was the Siemens burner, invented by Friedr. Siemens in 1879. In its original form this burner is a round-flame burner in which the flame burns around a central porcelain cylinder, over the top edge of which it turns. From this point the products of combustion pass downward through a central flue, and in their passage they heat a chamber through which the air passes upward, becoming highly heated by contact with the burner body. The products of combustion are then carried to the escape pipe by means of one or two side tubes.

This first regenerative burner gave a very powerful light, but it was clumsy and inelegant in form and appearance, the shadow cast by the large body of the burner was objectionable, and hence, it did not find much favor for interior lighting, although it was extensively applied for the lighting of streets, squares and parks and large halls. Regenerative gas lamps have since then been modified and constantly improved, and the Siemens inverted regenerative lamp is now manufactured in several different forms.

The Lungren regenerative lamp, which resembles the Siemens, is practically an inverted Siemens lamp, in which the flame burns outward and upward around a central shell which it heats to a high temperature. The air supply enters above the flame by means of tubes extending across the escape flue, and passes down on both sides of the flame. The flame is enclosed in a clear glass bell, semi-globular in shape, which is supported by a hinged ring.

Other regenerative lamps, some having the flame burning from the inside out and others from the outside towards the inside, and all similar in principle, but different in details of design and construction, are the improved Siemens, the Wenham, Bower, Clark, Grimston, Thorp, Gordon, Sugg, Bray, Brown's "Brilliant," Fullford, Meteor, Butzke, Westphahl and Muchall lamps.

For dwelling-house illumination regenerative lamps have, up to the present time, been used only to a very limited extent, although the fact that nearly all of these lamps are powerful ventilating agents and may be made to assist materially in the removal of the vitiated air of apartments, would

seem to recommend them particularly from a sanitary point of view. Their application has been largely confined to special cases, such as the lighting of large halls, stores, and for lighting streets and squares, and wherever used they have proven to be very economical in gas consumption. The burners of regenerative lamps are somewhat complicated, require nice adjustment and are liable to clog up with deposits of carbon, and need, together with the enclosing glass globe, frequent cleaning and attention. This, together with the high price of the lamps, has also acted as a drawback against their general introduction.

Among the latest regenerative gas lamps, especially adapted for interior lighting, I mention Sugg's patent "Cromartie" gas lamp. In these lamps "a special form of steatite burner is used inverted, with the object of retarding the motion of the carbon particles through the length of the flame, thus allowing sufficient time for the oxygen of the atmosphere to combine with the carbon of the gas in combustion. This arrangement produces an intensely white flame in the form of a camelia, diffusing a perfectly steady white shadowless light of great illuminating power." Each lamp is provided with a Sugg automatic leather diaphragm governor. These Cromartie lamps are made in two forms, either as ventilating or as non-ventilating lamps. In the ventilating lamps the heat developed by the combustion of gas is not only carried away without entering the room, but it is utilized to assist in educing heat or vitiated air from the apartments. In the case of smoking rooms this arrangement is particularly effective, and all smoke is rapidly conducted to the exterior. The air at the ceiling level is kept cool and pure, and furniture, pictures and gilt frames are not subjected to damage. The Cromartie lamps are said by experts to produce very high results in candle-power, the quality of the light is said to be excellent, and as these lamps are gotten up in a variety of pleasing and artistic designs, shapes and colors, they lend themselves admirably to decorative lighting.

Mr. MacFie, gas engineer, of the firm of Milne, Sons & MacFie, in a paper read at the annual meeting of the North

British Association of Gas Manufacturers in Edinburgh, in 1891, has pointed out one notable feature of all regenerative lamps, namely, that they throw the light downwards where wanted, whereas all flat-flame burners tend to light up the ceilings and upper parts of wall.

A further advance in the perfection of gas lighting has been made by the invention of *incandescent gas burners.* In these burners the heat of the flame is utilized in the raising to incandescence of some refractory substance introduced into the burner which is usually an atmospheric or Bunsen burner. This substance may be a basket of platinum, as in the Lewis burner, or a conical-shaped basket of a net work of magnesia as in the Clamond lamp, or a row of finely shaped parallel suspended rods of magnesia such as is used in the Fahnejelm light, or finally a funnel-shaped wick or mantle of cotton treated chemically with sulphate of zirconium, and other rare elements, such as yttrium, didymium and lanthanium, as seen in the Welsbach incandescent burner.

The Clamond and the Welsbach incandescent gas lights are being used to a great extent in Europe, and the Welsbach light to some extent in this country. The former is the invention of a Paris chemist, the latter of a Vienna chemist, Dr. Auer von Welsbach.

After being first put on the market the Welsbach burner disappeared again, owing to various imperfections. It has now again reappeared, in an improved form, as claimed by its manufacturers, but however beautiful the Welsbach incandescent light when the mantle is new, its light rapidly deteriorates and loses in intensity, and this is particularly the case where the atmosphere carries much dust, which settles on the mantle forming a sort of incrustation, which renders the light less incandescent and changes it from white to red. The chief objection to the Welsbach light which renders it undesirable for ordinary domestic use is, that the cotton mantle is extremely delicate and readily breaks, also that the glass cylinders surrounding the filament crack at times and in doing so break the mantle. As the mantle is expensive, the Welsbach light,

although undoubtedly very economical in the use of gas, proves in the end quite costly. Among its other advantages are the steadiness of its light, particularly when used with a volumetric governor, and the decreased radiation of heat as compared with other high-power gas lamps.

Quite recently the Welsbach incandescent lamps have been used in some European cities for street illumination, and it is claimed that favorable results have been obtained as regards lighting power.

My description of gas burners would be incomplete without a mention of the *albo-carbon light*, which gives a much increased illumination and a very white, soft and steady light, by the carburetting of the ordinary gas. This process consists in supplying to the ordinary gas, at the gas burner, a further amount of carbon illuminants. The enriching solid carbon material is kept in a vessel combined with the gas fixture, and the heat of combustion of the gas flame is used to preheat the gas supply and to vaporize the carbon, which thus enriches the gas, and effects a saving in the gas consumption.

[*To be concluded*]

THE ELECTRIC MOTOR.*

By Prof. F. B Crocker, of Columbia College, New York City.

The lecturer was introduced by Prof. E. J. Houston, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

A single lecture cannot possibly do justice to a subject of the magnitude and importance of the electric motor. There are, however, certain salient and interesting points which, when touched, give the keynotes of the entire subject. Some of these are contained in the history of the electric motor, and others in the action of the machine itself.

* A lecture delivered before the Franklin Institute, Philadelphia, January 19, 1894.

In taking up the historical consideration, we have the amber of the ancients as the first electric generator, corresponding to the dynamo, and its attraction of feathers and other light bodies as the first artificial production of motion by electricity, corresponding to the electric motor. I say *artificial*, because lightning has from the beginning of the world caused powerful movements and disturbances in the bodies which it strikes. Thus the birth of these two important machines was simultaneous; indeed electricity was discovered solely by the fact that it produced *motion* under conditions which were peculiar, and it seemed to be so different from all other natural phenomena that from those early times, even up to the present day, it is looked upon as the most wonderful and mysterious agency in nature.

The magnetic attraction of pieces of iron by the lodestone was also observed by the ancients, and the electric motor of the present day is more directly based upon this phenomenon than upon the electrostatic attraction caused by amber.

From those early times up to the present century, particularly during the last century, numerous experiments were made with magnetic and electrostatic attraction, but no one produced any results which can be considered to be any more like an electric motor than the simple experiments of the ancients. The first apparatus which in principle and construction sufficiently resembled the machines of to-day, to be properly regarded as an electric motor, was Barlow's wheel, described by him in his work on "Magnetic Attraction," published in London in 1823. This invention is remarkable in the fact that it antedated by eight years the disc machine of Faraday (which was the prototype of the dynamo), and his discovery of magneto-electric induction in 1831. Not only was Barlow's wheel far ahead of Faraday's disc in point of time, but it was also a much better construction, because the former was made in the shape of a star with long points so that the current was confined to the particular portion of the wheel which was between the poles of the magnet. In Faraday's disc, on the

other hand, the current produced in that part of the disc actually between the poles was at liberty to flow back through all the rest of the wheel. The armature was, therefore, completely short-circuited in itself, a feature which we know to be one of the worst faults that it can possibly have, and the amount of current obtained in the external circuit was an almost infinitesimal fraction of that produced, being only sufficient to deflect a galvanometer needle. It was, indeed, a fortunate thing for science that any perceptible effect whatever was obtained, otherwise the most important discovery of the nineteenth century might have been delayed.

Joseph Henry, in 1831, was the first to construct a motor which worked by electro-magnetic attraction. This apparatus really has a better right to the distinction of being called the first electric motor than Barlow's wheel. Many other inventors followed Henry in devising forms of electro-magnetic motors. Jacobi in 1834, Davenport in 1837, and Page in 1838, are particularly worthy of mention. Some of these early motors were by no means mere toys, but were of considerable size and power. Jacobi, of St. Petersburg, in 1838, propelled a boat twenty-eight feet long at a speed of three miles an hour; and Page, of Washington, in 1851, succeeded in obtaining a speed of nineteen miles per hour with a car carrying a number of persons and driven by a sixteen horse-power electric motor. This result, by the way, is practically the same as that obtained from the most improved trolley cars of to-day, both in speed and power.

This brief glance at the early history of the electric motor brings out the striking fact that this machine was invented eight years before the dynamo and for several decades it was considered of more importance, both scientifically and practically; the motors of Jacobi and Page, for example, being far more powerful than any contemporaneous dynamo. A search through the patent records of the United States and England would show also that more attention and greater expectations were then based upon the motor. This was undoubtedly due to the fact that inventors hoped to obtain a source of power which would rival or

surpass the steam engine. It was gradually realized, however, that the cost of electrical energy obtained from a primary battery is so high that it cannot compete with a steam engine. The number of pounds of zinc consumed in the best battery, per horse-power hour, is about equal to the weight of coal required to give the same amount of energy in a steam engine; and since zinc costs about fifty times as much per pound as coal (in fact it actually requires several pounds of coal to produce one pound of zinc), it is obvious that the primary battery is far more costly than steam in the generation of power. As a matter of fact, electrical energy from a primary battery at the present time costs at least ten times and probably twenty times as much as that obtained by the use of a steam engine and dynamo.

The realization of this serious difficulty greatly discouraged scientific men and inventors in regard to the electric motor. A reaction set in against it, and for many years it was comparatively neglected by the best workers. The dynamo was taken up in its stead and developed in the remarkably rapid and successful manner which is the greatest practical achievement of recent times. The neglect of the electric motor continued until about 1887, the dynamo having by that time reached a state of great perfection and being in extensive use for electric lighting. The development of the dynamo, and the laying of electric light circuits through the streets of many cities and towns, provided the very supply of reasonably cheap current which was needed for the motor, and which the primary battery had failed to give.

This fact encouraged inventors and manufacturers to again take up the motor, and since that time its progress in this country has been very rapid; but even now the motor is somewhat overshadowed by the dynamo. The number of electric motors in use in foreign countries is not very considerable, but in the United States there are probably about 50,000 stationary motors and several thousand railway motors, whereas the number in the whole of Europe is not much more than one-tenth of these figures. This last fact probably explains why the literature of the dynamo is

much more complete than that of the motor, since most of the books are written by Europeans—the time of Americans being occupied rather with *making* and *using* dynamos and motors than with telling others how to do these things. The most recent history of the motor includes the invention, by Tesla, in 1888, of the two-phase alternating current motor and the development of the two- and three-phase systems. These important systems are now being practically used, and an enormous electric power transmission plant is being installed at Niagara Falls, which is to be operated by the two-phase system. Indeed, it may be said that the progress of the electric motor at the present time is equally as rapid as, and more interesting than, that of the dynamo.

If the dream of the electrical engineer should be realized and electrical energy could be obtained directly from coal without the use of the steam engine and dynamo, then the importance of the electric motor would be paramount, and it would be used in practically every case where power is needed, while the steam engine and dynamo would be relegated to scientific museums where they would be gazed upon as mere historical curiosities. This time may come in a few years, or perhaps not for centuries, but no one will dare deny its possibility, and many of the greatest thinkers and experimentalists are now working in that direction.

The points in the history of the electric motor to which I desire to call particular attention are these: that for many years it was considered of greater importance than the dynamo; that it then fell into a position of comparative insignificance, but that in the last few years it has again become very prominent, and in the future it is certain to be of still greater importance, while the dynamo may become obsolete.

In considering the construction and action of the electric motor, the first and most important fact is its great similarity to the dynamo, or, more strictly speaking, it is practically the same machine used in exactly the opposite manner. The dynamo is a machine which generates electric current when driven by mechanical power. A motor is a machine that develops mechanical power when supplied with electric

current; thus the functions of the two machines are exactly the converse of each other; nevertheless, identically the same machine can be used for either purpose, that is to say, the machine is perfectly *reversible*. It is also a fact that a machine that is good for one purpose is good for the other. The old idea that a good dynamo was not necessarily a good motor, and that considerable differences in construction are required, is, so far as the writer's experience goes, a fallacious one. The tendency now is for manufacturers to make exactly the same machine and use it for either purpose indiscriminately with only very slight differences in the details of winding, connections, etc.

While it is true that the two machines are practically identical in construction, nevertheless, their actions are somewhat different, and this difference is just sufficient to be puzzling. It seems to be a fact that knowledge concerning the motor is much less general and much less perfect than knowledge of the dynamo. The reason for this is probably that most persons fail to understand these slight differences in action and are therefore apt to assume either that the two machines are exactly alike or entirely different, neither of which assumptions is correct.

The key to the action of the motor and particularly to the difference between it and the dynamo is its *counter electromotive force*. In the case of the dynamo there exists only one EMF, whereas in the motor there must always be two. The difference between the two cases may be expressed very simply in the following way:

One Kilowatt dynamo,

$$C = \frac{E}{R} \tag{1}$$

$$10 \text{ ampères} = \frac{100 \text{ volts}}{10 \text{ ohms}}$$

One Kilowatt motor,

$$C = \frac{E - e}{R'} \tag{2}$$

$$10 \text{ ampères} = \frac{100 \text{ volts} - 90 \text{ volts}}{1 \text{ ohm}}$$

C is the current;
E, the direct EMF;
e, the counter EMF;
R, the total resistance of the circuit;
R^1 the resistance of the armature.

The current and direct EMF are the same in the two cases, but the resistance is only one-tenth as much in the case of the motor, the difference being replaced by the counter EMF of 90 volts, which acts like resistance to reduce the current.

The counter EMF of a motor is the *necessary* result of the rotation of its armature, as I will now show you by the following experiment. We have here two identical machines, one of them being connected to the electric light circuit, the current from which causes the machine to run as a motor. This machine is belted to the other machine, which is thereby driven as a dynamo. Now in both cases we have identical armatures revolving at equal speed in magnetic fields of practically the same strength. It is obvious, therefore, that nearly the same EMF must be generated in each machine, because in both cases practically the same number of lines of force are cut by an equal number of turns of wire revolving at the same speed. In the case of the dynamo this EMF produces a current which may be used to feed a certain number of incandescent lamps. In the case of the motor the EMF is opposed or counter to the direct EMF of the electric light circuit, and the current produced is due to the difference between the two, as expressed in equation (2).

It may be asked why this EMF is necessarily a counter one. The answer is that if we trace out the direction of the motion and of the lines of force, we shall find in every case that the EMF generated is opposed to that which produces the rotation of the armature. This in fact necessarily follows from Lenz's law. The real significance of the counter EMF is that it represents the amount of electrical energy that is taken out of the electrical circuit, so to speak, and converted into mechanical energy.

This is the way in which nature always works in converting electrical energy into any other form of energy, with the single exception of the production of heat by the passage of

current through a resistance. This last, however, is not a true case of conversion, being a frittering away of energy similar to the production of heat by friction. In all other cases the counter EMF is always present. For example, when electrical energy is converted into chemical energy in the charging of a storage battery, or the decomposition of water, there is in every case a counter EMF. In the same way, when an electro-magnet is charged and electrical energy is converted into magnetic energy there is a counter EMF which opposes the magnetizing current and is commonly known as the counter EMF of self-induction. Even when electrical energy is converted into heat by the Peltier effect there always exists a counter EMF which represents the conversion of energy, this being a reversible process, and, therefore, a true case of conversion, which, as already stated, is not the case when heat is produced by mere resistance. This counter EMF is indeed a most remarkable and interesting phenomenon and throws considerable light upon the relation of the various forms of energy and the manner in which one is converted into another.

In the case of the motor, the counter EMF actually represents the amount of electrical energy converted into mechanical energy, and therefore determines the efficiency the so-called electrical efficiency, or conversion-factor, being equal to

$$\frac{\text{Counter EMF}}{\text{Direct EMF}}.$$

The actual or commercial efficiency is somewhat less than this, owing to friction, Foucault currents and hysteresis. The counter EMF also determines the speed and many other facts in the working of the machine.

In the minds of many persons the counter EMF is thought to be merely a "scientific idea" or a mathematical abstraction which has no real existence or importance. Nothing could be more erroneous than any such opinion. The counter EMF is just as real as the direct EMF. We have already seen that it must necessarily be produced whenever the armature revolves. It is somewhat difficult, how-

ever, to actually measure or show it. From its very nature it is covered up, so to speak, by the direct EMF. The ordinary way to determine it is to find the value of the direct EMF, the resistance, and the resulting current; the counter EMF is then found by the following equation, which is derived from equation (2): $e = E - CR$. It is also possible to calculate it in the same way that the EMF of a dynamo is determined, if the number of turns of wire, speed of rotation and number of lines of force are known.

The following experiment actually shows the existence and value of the counter EMF. We have here a plain shunt-wound motor provided with a fly-wheel, and we run it from a constant potential circuit of (say) 110 volts, and while it is running at full speed it is entirely disconnected from the circuit, but it will continue to run by the energy of the fly-wheel, and it will then act as a dynamo and generate an EMF of nearly 105 volts, which is tested by connecting a volt meter to the two brushes. This EMF is practically identical with the counter EMF which the machine was producing the moment before while running as a motor, provided, of course, the test is made immediately, so that the speed does not have time to fall appreciably. It should be remarked, also, that the strength of the field magnetism is slightly less, owing to the fact that it is fed by the EMF of 105 volts generated by the machine itself, instead of by the 110 volts of the circuit; but if the magnetism is nearly saturated this will only reduce the number of lines of force one or two per cent. Several incandescent lamps can be connected in parallel across the terminals of the machine and the energy in the revolving fly-wheel is sufficient to keep them glowing for one or more minutes. If a lamp is kept connected across the terminals of the motor while the switch controlling the circuit is alternately opened and closed, it is possible in this way to compare the direct and counter EMF by the variation in the brightness of the lamp, and it will be seen that the latter is only slightly less than the former.

A still more striking demonstration of the reality of the counter EMF will now be given by running the motor with a certain amount of resistance in its shunt field circuit, so

that the field magnetism will be below its normal value, in which case the speed will be higher than usual. If the machine is now disconnected from the circuit and the resistance is afterwards cut out of its field circuit, the EMF produced will become actually higher than the original direct EMF; in fact, it is possible to obtain two or three times the original voltage. We have here a new method of converting electrical energy to a higher potential, being a sort of direct current transformer, which, however, is quite different in principle from the ordinary dynamotor.

The important matter of governing the speed or power of electric motors depends largely upon the phenomenon of counter EMF. For example, the various methods of regulating street car motors, *i. e.*, the simple rheostat, the "loop" for short-circuiting one of the field coils, the "commutated fields" and the "series parallel controller," all act to adjust, or make up for, the variations in counter EMF which result from changes in speed. The most awkward matter in working electric motors is to control the current when the counter EMF is very low, due to the fact that the motor is starting or running slowly, and up to the present time there is no very satisfactory solution of this problem. The introduction of resistance in series with the armature is usually the simplest and most successful plan, but this is very wasteful of energy and involves the use of a large and clumsy rheostat.

The paradoxical fact that the speed of the ordinary shunt-wound motor increases if its field magnetism be weakened is also due to the counter EMF. This is easily understood if we remember that the counter EMF is reduced by weakening the field magnetism, consequently the current is increased in strength, as is evident from equation (2), and the speed therefore rises until the counter EMF reaches a sufficient value to shut off the excess of current.

The writer showed, several years ago, in his lectures at Columbia College, that a motor can easily be designed to run at the same, or at a *higher*, speed, when fully loaded than when lightly loaded. This may be done by slightly exaggerating the effect of armature reaction so that the field magnetism will be considerably reduced by the large

armature current which flows at full load, thus diminishing the counter EMF and increasing the speed in the manner just explained. In this way the remarkable effect of greater speed with heavier load is obtained without any special device or construction, all that is necessary being a slight modification in design involving no increase in cost or complication.

These examples demonstrate the great significance and importance of the phenomenon of counter EMF in the action of the electric motor.

EMERY AND OTHER ABRASIVES.*

By T. Dunkin Paret,
President of the Tanite Company.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

Mr. Chairman, Ladies and Gentlemen, Members of the Institute:

In opening the consideration of the subject of my lecture, the first question that naturally arises is, what is emery?

I asked this question myself many years ago, before I ever had a thought of any connection with the industry of abrasive materials. On rainy days, in my early boyhood, my mother's sewing table, mahogany and claw-footed, was a source of unfailing interest. From its triple drawers and manifold little compartments, various wonders were evoked and from these wonders a small boy's curiosity evoked wonderful explanations. Among these wonders was a lifelike strawberry of red cloth, embroidered in green and yellow. Its brightness attracted me; its heaviness surprised me, and I wondered why my mother thrust her needle through the little strawberry. I asked her what the strawberry con-

* A lecture delivered before the Institute, February 9, 1894.

tained, and she answered, "Emery." I asked her what emery was, and she answered, "Steel dust."

Since then others have repeated the same question, and have received an answer fully as remarkable as the one my boyish ignorance drew forth. One of these answers, published several years ago in a mechanical paper, contains such a delightful mixture of fact and fiction, and is so characteristically expressed, that a few *verbatim* quotations may be interesting enough to place on record.

"Emery," says this oracle of the correspondents, "is a natural mineral rock, not found in mines or in strata, but scattered over more or less all the earth. It is a silicate of alumina, contaminated or mixed with a trace of iron. It is the matrix, or mother rock, of the ruby, the emerald and the sapphire. On account of the fact that emery is more generally found in Turkey or Turkish Asia, where labor is cheap, we procure emery from that country. Nearly 100 years ago, Robert Bruce Goldsworth, of Manchester, England, bought from the Turkish government a firman, or right, to collect and deal in emery. He formed the Levant Mineral Company, of London, and to this day emery is collected and mined by this body. Arabs (generally two, with a miserable camel) wander over the country with a bunch of jointed iron rods furnished with a steel point, so tempered and sharpened that, when they have reason to believe a lump or fragment of emery is below the soil which indicated it, they can, by jabbing at it with their steel rod, determine not only how deep it is buried, but also how large it is. If the indications are that it is of too great size for them to handle, they leave it. If the contrary, they dig it out—or pry it out—and by means of fire heat it; and when hot, crack it up by throwing water on it. When it is cracked and broken, so that they can handle it, they load it on their camel and carry it to Smyrna, where the foreman of the Levant Mineral Company buys it of them. In this crude way about all the emery of commerce is collected. The crude emery is sorted and corded up in grades, and vessels trading to that country for figs and other fruit load up more or less of it as ballast under their cargo." "This

is emery and its history. It is not found in mines, like coal, or iron, or copper, but as I have described, and, though it is claimed to be found elsewhere, Turkish Asia may be said to be its home, and the cheap, shiftless Arab laborers, who will work for days for a few piasters, is the reason, chiefly, that it is not looked for elsewhere. Almost every stone fence in the United States contains rock or boulders, which, if crushed and graded, would do the same work, but in this country it would not pay to collect it."

A much more important inquirer than this newspaper correspondent has lately asked the same question, "What is emery?" Unless we are mistaken, one of the questions addressed by the United States Government to those in the emery industry was whether they considered emery a chemical compound or a mechanical mixture.

Our own answer to the general question is, that emery is a mineral, of such rare occurrence and such mysterious origin, as to excite the interest of geologist and mineralogist. At some time in the past and by some means, both at present unknown, its special value as a grinding material was discovered, and it became an object of steadily growing importance in the industrial world.

We know of no facts bearing on the use of emery by the ancients. Archæologists have tried to prove that the ancients cut out their huge blocks of hard stone by the use of saws studded with corundum, but the evidence is of a negative character and purely fallacious. It seems to rest on the assumption that, as the diamond cannot be used for rock work, corundum must have been so used. It is a general belief, shared equally by workers and by scientific men, that carbon, or black diamond, is the only form of diamond which can be used to work stone, and there is no evidence that carbon, or black diamond, was known to the ancients. As a general rule carbon possesses a toughness which renders it a specially fit tool wherewith to drill rock or turn down solid emery wheels; while the gem diamond is so brittle that it breaks off quickly under the same work; and bort, so crystallized as to shiver easily into small pieces. But this general rule has so many proved exceptions, that

it is unsafe to connect definite qualities with the three species of minerals.

Until about fifteen years ago my personal experience confirmed the general belief. The diamond gem always proved too brittle for use, its points being broken off almost as soon as it touched a revolving emery wheel. Bort, of all varieties, proved far worse, and shivered to pieces. Carbon, or black diamond, seemed to be the only mineral hard enough and tough enough to cut down a revolving solid emery wheel, without being itself either broken or rapidly worn. Nevertheless, the very great variability in the quality of carbon ought to have suggested at an earlier date an equal variability in diamond and bort. The variation in quality of carbon is very great, some stones having very great lasting power, while others wear off so rapidly as to be absolutely useless. Carbon though they are, any common stone would do as well. As to their real value there seems to be no index. In the trade, unbroken crystals are considered more valuable than fractured stones, and the glossy black is preferred to gray. To such an extent does this question of color affect the choice that it is a common custom to blacken the carbon by artificial means. So misleading, however, are all the appearances, that, after many years' experience in the use of carbon, and in its observation under a powerful glass, the most experienced expert will sometimes select worthless stones.

My first experience of the unreliability of the general rule as to bort occurred to me probably ten or fifteen years ago, when two or three pieces were sent to me from Canada, with the statement that a friend at the Cape of Good Hope had sent them on as samples of a bort adapted to take the place of carbon. Thorough trial proved the correctness of this statement, but before any arrangement could be made the original sender had gone to India, and was lost sight of, and inquiry failed to discover the identity of the mine.

After the lapse of many years, in 1893, bort again came into notice for use instead of carbon, being offered at $2.50 per carat as against $16.50 for carbon. This bort has now had over six months' trial, and answers as well as carbon

for all except the very hardest use, though its shape is not quite so satisfactory. Thus far I have been unable to find out where this bort came from, or how its quality is ascertained.

In 1883, I bought 125 carats of diamond for $2 per carat. This was one-half of a lot left for sale with a New York firm, and its origin and quality were both unknown. This lot of 125 carats produced 260 tools, each containing an unbroken crystal, and all of these were as useful for turning solid emery wheels as was the more costly carbon, except as in the case of the bort, for the very hardest use; such use being the treatment of very hard wheels of coarse grain. These diamonds were much more satisfactory in shape than the bort. The remainder of the lot was removed from the city unsold and could not be traced.

As both diamond and bort could have accomplished the necessary work in ancient quarries, the claim that the ancients must necessarily have used corundum falls to the ground.

In no museum or cabinet have I ever seen an ancient tool of emery or corundum. The only emery tool of unknown age which has come to my notice is an Indian hammer stone of the ordinary type; but it is of emery and was found in 1893, in Westchester County, New York. As emery is a surface rock in some localities in that county, there is nothing to indicate that the quality of the stone dictated its choice, and its exceptional character would indicate that the Indians or other early inhabitants had not discovered the superiority of emery in hardness over the other surface rocks.

The natives of Ceylon and India use corundum with which to grind and polish gems. It is probable that this use has come down to them from their ancestors, but we have little knowledge as to the origin of the process.

Emery is essentially a modern commercial product, its use being dependent, firstly, on the enormously increased use of iron in very recent times; secondly, on those metallurgical processes which have produced steels, phosphor-bronzes, chilled iron and other specially tempered

metals; and thirdly, on that development of steam-power which has led to the use of high-speed rotary grinding tools.

Among the earlier uses of emery is its application to the lapidary's wheel. Its use on paper and cloth is also probably an early one. To this, succeeded the wooden wheel, banded with leather, which was coated with glue and rolled in emery. This was followed by the solid emery wheel. A still later production is the emery millstone. Glass, granite and the metals are the principal substances on which emery is used. The purposes for which it is used are roughly and rapidly to remove material—to shape and form, and to smooth or polish.

Emery was chosen for this purpose (before any commercial supplies of corundum existed), because of a grinding quality it was supposed to possess in a higher degree than that belonging to any other material. This grinding capacity was based on its rank in the scale of hardness among other minerals. The assumption that hardness was the main factor in its value has vitiated all judgments respecting grinding materials. Roughly speaking, emery was described as next in hardness to the diamond, and the superficial experimenter in testing a sample at once proceeded to notice how readily it would scratch glass or would crush under pressure. The next unfounded inference was drawn by those not altogether superficial observers, who sought to establish the value of a sample by a theoretical test. As alumina seemed to be the characteristic component of emery, that emery was deemed the best which contained the most alumina.

When corundum was found in such quantities as to be of commercial value, this theoretical text was urged strongly. It was pointed out that corundum contained a larger proportion of alumina than emery; that it contained none of that iron which was said to contaminate emery, and that it was, therefore, purer. Purity had been repeatedly claimed for corundum from different mines as a measure of value. In the sapphire corundum is said to take its most nearly perfect form, and in Klaproth's analysis of a blue sapphire,

quoted by Prof. J. P. Lesley,* the percentage of alumina is given as 98·5, and that of the impurities as only 1·5, the latter consisting of 0·5 per cent. silica and 1·0 per cent. iron. The peculiarity of the sapphire is that it is so fine and hard as to wear down, when ground, into smooth, flat faces. Such a stone, after being cut or ground, would scratch or cut only with its artificial angles, and these if much used would wear down to flat faces. If, instead of being held against a grinding wheel and so flattened, these gems were moulded into a solid wheel, they would, in like manner, flatten and would cease to cut as soon as their angles were worn away. Their fineness, their hardness and their purity, would be the very qualities which would unfit them for use as grinding materials.

Excessive hardness, therefore, is not the only requisite in a material used for cutting other substances. The most nearly perfect carbon will, if used for turning emery wheels, lose every point and corner and become a rounded mass, useless for further turning unless it is broken so as to present new angles.

Nevertheless, the supposed purity of corundum has invested it with such a fictitious value that the manufactured article has commanded as high a price as $200 per ton, when emery was selling for from $40 to $75. In museums and cabinets, specimens of corundum may be found which show distinct seams of bright, blue, transparent sapphire, and others of so-called ruby corundum, not transparent, but only suffused with a mild pink. If commercial corundum consisted of this blue transparent gem, purity would be the first thing claimed, the mere resemblance to sapphire and ruby being taken as a proof of purity.

Unfortunately for this assumption, Professor Lesley states that "both sapphire and ruby may be very impure corundum;" and he gives an analysis of a ruby containing only forty per cent. alumina and of sapphire containing only fifty-eight per cent.

Very little commercial corundum comes from sapphire-

* *Second Geolog. Surv. of Pa.*, C 4, p. 352.

streaked seams, and scarcely any from massive rock: a small portion is produced from separate large crystals, which occur in some formations, scattered through a softer rock. The greater part, however, is found in large, decomposed and broken-down seams. In the case of the large crystals purity would depend on the care with which all traces of the matrix were removed. In the case of corundum sand, washed out of broken-down seams and beds, purity would depend on the separation of the corundum granules from the mixed mass of which they form a part.

The maximum purity of which we can find record is exhibited by the sapphire referred to by Professor Lesley as containing 98·5 per cent. of alumina. In reference to our assertion that, if crystallized in the form of a gem, corundum would be too fine and too hard to serve as a grinding material, it will be safe to qualify it by the statement that there might be some lower point at which purity had a real value. The practical question, therefore, is: how does corundum lately produced on a commercial scale compare with emery so produced?

In 1893, Dr. T. M. Chatard analyzed three samples of American corundum, purchased of three different mills. In these the average of alumina was 64·65 per cent. At the same time he analyzed three samples of emery from three different sources. The average of these was 60·94 per cent. of alumina, a difference of only 3·71 per cent. in favor of corundum. Of the three emery samples one was of that American ore which the combination of American emery mills has declared to be spurious and worthless. This American emery contained only 53·59 per cent. alumina, and if this sample were omitted the analysis would stand as follows: Corundum, 64·65 per cent. of alumina; emery, 64·62 per cent., a difference of three-one-hundredths of one per cent. in favor of corundum.

Of the three corundum samples, one contained only 37·31 per cent. of alumina, which is 16·28 per cent. less than the American emery contained. This corundum was of such color and general appearance that it might easily deceive the ordinary commercial user, and we are forced to believe

either that it did deceive its producers and sellers, or that they knowingly deceived the public. On going further into these analyses, we find that the American emery contained only 0·26 per cent. of silica, while the corundum just referred to contained 44·64 per cent. Going still further, we find that the corundum contained only 14·60 per cent. of ferric oxide, while the American emery contained 41·31 per cent.

In these facts we find a simple explanation of the popular delusion as to the superiority of corundum over emery. It is a question of color. The sapphire ranks next in hardness to the diamond, and is assumed to be a typically perfect grinding material. Corundum is a form of sapphire, occasionally containing traces of transparent blue sapphire, but characterized as a general thing by a yellow-toned whiteness. The 44·64 per cent. of silica in the so-called corundum furnishes that light color which characterizes corundum, while the 41·31 per cent. of ferric oxide in the American emery so darkens it as to disguise its higher proportion of alumina It does not require a chemical analysis to find this alumina in the emery. It is not obscured or hidden away in subtle chemical combinations. It is present often and freely as pure, blue, transparent sapphire, visible sometimes to the naked eye and easily discovered by a pocket magnifying glass. It can be seen at times, bright and blue, in the mass of a solid emery wheel, the general color of which is black, and if some of the dirty brown emery is sprinkled on a sheet of white paper and examined with a good glass in a good light, many grains will be found which are composed entirely of transparent, blue sapphire. If the unsightly ore is fractured at the ore heap it will often be found studded with the shining gem. It is not claimed that all emery is thus characterized, but the occurrence is so frequent as to prove that alumina in one of its highest forms of crystallization is a striking feature of old world emery.

If the commercial values of corundum and emery are based on their relative purity (a high percentage of alumina being considered the criterion), then these analyses show only a trifling superiority in the corundum. It may be suggested that these late analyses of Dr. Chatard are based on

unusually poor samples of corundum and unusually good ones of emery. To show that this is not the case we cite* nine analyses of corundum quoted by Professor Lesley, the average of which is 83·15 per cent. of alumina. So far as we can judge, none of these refer to American corundum, and none to commercial corundum, all of them relating to actual gems or cabinet specimens. We cite, also, ten analyses of Dr. J. Lawrence Smith.† These relate to samples of emery from four localities in Turkey and Greece, and the average of the ten is 67·97 per cent. alumina, or 7·03 per cent. more alumina than is shown by Dr. Chatard's analyses.

As popular belief assumes hardness to be the prime requisite in a grinding material, the question now arises as to whether hardness is definitely proportioned to the percentage of alumina. The ten analyses of Dr. Smith just cited give a striking answer. They show that the gradation of effective hardness does not correspond with the gradation of alumina. Assuming the effective hardness of East Indian sapphire as 100, the highest standard reached by any of Dr. Smith's samples was 57. This sample contained only 63·50 per cent. of alumina, while that which contained 77·82 per cent. (the highest percentage of alumina shown) ranked only 47 in the scale of hardness, or 10 less than did that sample which contained 14·32 per cent. less alumina.

These analyses throw a strong light on the popular delusion as to the injurious effect of iron as a constituent of emery. It is not an uncommon thing for buyers to say that some particular commercial brand of emery contains so much iron that they cannot use it. As a rule, no defect in use is set forth, and the inference is probably made from weight, from color, or from the action of a magnet. In the ten samples of emery analyzed by Dr. Smith, the lowest percentage of iron was 8·62, and the hardness 47; while the highest percentage of iron was 33·25, and the hardness 57. In this case quadrupling the amount of iron increased the hardness 10 per cent. While the gradations of hardness do

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* *Geolog. Sur. Pa.*, Chester County, C. 4, pp. 352, 353.

† *Am. Jour. Sci. and Arts*, **2**, x, 366.

not vary uniformly with the percentage of iron, it is a striking fact that in this one case the highest percentage of iron is accompanied by the greatest hardness.

While Dr. Smith's analyses show that a high percentage of iron does not imply a diminished hardness, Dr. Chatard's analyses show that a low percentage of iron does not imply a large percentage of alumina. That sample of corundum which contained only 2·90 per cent. iron contained only 72·26 per cent. of alumina, while that which contained 9·70 per cent. of iron had 84·38 per cent. of alumina.

It is not only the superficial user who is particular as to the amount of iron in his emery, for, in 1892, an enquiry for emery was sent out from one of our United States arsenals, which stipulated that the emery must not contain over 15·00 per cent. iron, and that it would be tested by the magnet.* Of the ten samples analyzed by Dr. Smith only two had so small a percentage as 15, so that it is doubtful if any commercial emery is to be found of the standard demanded in this case by the United States Government. It has already been shown that the maximum hardness of these samples was 57, and that the sample which had 8·62 per cent. of iron ranked only 47. The only other sample low in iron contained 13·06 per cent., and ranked only 46.

* Since the delivery of this lecture an order has been sent out from one of the United States arsenals for emery "averaging not over ten per cent. of iron, to be tested by the magnet." As I can find only one analysis which shows less than ten per cent. of iron, it is almost certain that no commercial supply exists, and that such a demand could only be met by the use of some very rare lot.

The wording of the demand implies that the percentage of iron is to be determined by the magnet.

As a recent letter from a corundum company appeals to the magnet test as a proof of the purity of its corundum, asserting that certain Southern corundum contains thirty per cent. of iron, I have had samples of three lots of corundum, from two producers, pulverized so as to go through a cloth with 200 meshes to the lineal inch. I find that this dust is so impregnated with iron that the magnet will attract and remove *every particle*, there being no residue at all.

If emery is to be condemned because the magnet attracts it, why is not corundum also condemned? Probably because of the unwarranted assumption that commercial corundum lives up to the letter of its type and is free of iron.

Analyses* of emery made by different authorities vary considerably in form. Most of them make no distinction as to the character of the alumina, but class it all under one head. Dr. Smith's analyses are of this nature, though he distinctly says that "we must not always regard the quantity of alumina as an indication of the quantity of corundum in the emery." Dr. Chatard's analyses follow a different plan. They make a distinction between dissolved alumina and insoluble corundum. Of the three samples of corundum analyzed by Dr. Chatard, one contained 47·60 per cent. of insoluble corundum, while one sample of emery almost equalled it and contained 40·21 per cent. A second sample of corundum contained only 36·49 per cent., and a third none at all. This last affords the astonishing contrast of a commercial corundum, possessing some of the external features of the genuine article, sold at the highest market price, and whose analysis shows no insoluble corundum at all, while a commercial article of American emery, whose enemies declare it to be spurious and worthless, contains 10·14 per cent. of insoluble corundum.

While the reputation of corundum depends partly on its supposed possession of a high percentage of alumina, it is also based on that standard of effective hardness, whose origin is credited to Dr. Smith. His method (often adopted by later investigators) was to place emery or corundum on a piece of glass, rub the emery over the glass with a piece of agate, until the emery is reduced to an impalpable powder, and then to weigh the glass and ascertain the amount removed. Sapphire was treated the same way, and

* As bearing on the comparative hardness of corundum and emery, a tabulation of Dr. Smith's is noticeable.[1] He shows the average effective hardness of six samples of eastern corundum to be 62, the highest being 77 and the lowest 55. The average effective hardness of the first six samples of emery in same tabulation is 52, the highest being 57 and the lowest 46. The three poorest samples of corundum (out of six) foot up 170° of effective hardness, while the three best samples of emery (out of the six averaged above) foot up 169. If, therefore, effective hardness is the great desideratum in abrasives, it would seem that $150 a ton is a large bonus for corundum buyers to pay on such chances as this tabulation indicates.

[1] *Am. Jour. Sci. and Arts*, 2, xlii, 89.

its result stood as 100 in the scale. This method appears, at first sight, to be exact, but it assumes a uniform hardness for sapphire, though such uniformity is doubtful in the extreme, and it also assumes uniformity in the resisting power of glass, which uniformity is equally doubtful. Its greatest defect, however, is that it omits two of the most important factors in the economical or commercial problem, *i. e.*, the time and the power. Even if it does determine the effective hardness of grinding materials it does not determine their grinding capacity in any such way as to establish relative commercial values. The commercial question is not settled by the statement that a given material will grind off a given amount of glass or metal. It must also be stated how long it takes to grind and how much power is consumed. This question will be considered later.

Even if it could be proved that the relative hardness of corundum and its percentage of alumina entitled it to a higher commercial value than emery, the manner in which corundum occurs at the mines makes it doubtful if a uniform product can be secured. In one form, probably the purest, it occurs in thin seams of bright blue sapphire, coated with a mineral of totally different nature. In another it occurs as distinct crystals of considerable size, encased in a softer matrix. As an example of this latter, I here exhibit crystals recently obtained from Lehigh County, Pa. In another form it occurs in decomposed or broken-down seams. Dr. Chatard remarks* that "the crushing of emery is generally much easier than that of corundum, though in this respect great differences often exist between the corundum of different localities and even in that from different parts of the same mine. This is probably due to the tendency of corundum to alter or weather. The researches of Prof. F. A. Genth and others, have shown that it yields readily to the action of mineral solvents, becoming softer and more friable, the alumina uniting with other substances to form various other minerals." * * * "Even when the change is very slight and invisible to the

* *Min. Resources of U.S.* U. S. Geol. Survey. 1883–84, p. 718.

eye we may have a material apparently solid and unaltered, which though crushing easily and giving a product of good appearance, not only yields too large a proportion of the comparatively useless 'flour,' but even a grain deficient in cutting effect."

No such crushing indictment as this can be brought against emery. It has no such tendency to weather and decompose. Sand veins are unknown and the emery rock occurs in mass. We have noted only two exceptions to its character for absolute stability. Professor Shepard has reported a gain in weight of manufactured emery amounting to two per cent., which gain was due to oxidation. An old sample case of "Wellington" emery, which had remained many years unmoved in a garret impressed me with the truth of Professor Shepard's report, but I have only met with this one instance. I cannot believe that as a common thing it undergoes any change whatever in composition. If acids or other artificial agents were employed to give that reddish-brown color which is mistakably accepted by some as a criterion of good emery, that might account for oxidation after manufacture. The other exception occurs in the case of some American emery. This emery is sometimes found in amorphous masses of considerable size, often of many tons weight, surrounded by earth and detached from other rock. Where these masses thin out at the edge they occasionally contain iron pyrites, and the rock thus tainted crumbles to pieces after short exposure to the weather. The indications of this taint are so clear that there is little excuse for one who mines such ore. As a rule this contamination affects only a small part of the edge of the mass; so small a part that it is not easy to see how even careless mining could have furnished enough to greatly lower the general average quality of the rock. I have seen one large deposit, however, where the presence of pyrites is so general as to suggest doubt about the average quality. A very old ore pile of many tons gives evidence of some change since the ore was mined, though there is no serious crumbling. It is quite possible that the mining of such ore gave American emery that bad character which effectually stopped its sale about twenty years ago.

Professor Shepard cites reports from the United States Arsenal, at Springfield, Mass., which make a most favorable showing for the emery mined in Hampden County, Mass., when such emery was used under so-called test conditions, and compared with corundum. On the other hand, it has been stated on good authority that this emery was so soft that it crushed down like mud and that the workmen would not use it. While it is possible that these contradictory verdicts or results may be reconciled by the existence of a real and great difference in quality, it is probable that the test was reasonably accurate and the bad opinion based on prejudice or misuse. Appearance probably had much to do with it. That emery which was considered standard had a reddish-brown color after manufacture and when offered for sale. This color was erroneously considered a necessary indication of good emery, while the emery from Hampden County, Mass., and Westchester County, N. Y. (which were put on the market about the same time), lacked the reddish-brown color, and presented a mixture of black and white. The white was at once condemned as an impurity and considered as an admixture of softer stone; and the same public which, of late, has set a high value on corundum, because of its whiteness, set a low value on American emery for the same reason. It is a fact that unbroken lumps of Greek and Turkish emery present, commonly, a reddish-brown appearance and that the emery of Westchester County, N. Y., when broken according to its natural seams and clearages, often shows the same color. The oxidation which causes this is the result of slow action during hundreds and thousands of years, and internally the color is different. A clean fracture of American ore shows color from glossy black to deep blue and light gray. The only colors mentioned by Dr. Smith for Greek and Turkish emery are dark gray, dark blue, and dark blue bordering on black. Dr. Smith says that "when reduced to powder it varies in color from dark gray to black. The color of its powder affords no indication of its commercial value." Nevertheless a reddish-brown color is the test of orthodoxy in emery, and the public regards all other colors with suspicion. Any

distinctive color imparts uniformity of apppearance, and, though emery is a mechanical mixture of most varied character, the public prefer uniformity in appearance.

The differences in composition of emery revealed by chemical analysis are confirmed by observations of a more general nature. Dr. Smith enumerates several varieties. One has "small points of a micaceous mineral disseminated in the mass." Another is fine grained and free from micaceous specks. Another is coarse grained. Another lamellated and containing an abundance of micaceous mineral. Dr. Smith also states that specimens containing the same amount of corundum differ in their effective hardness. These observations, reported in 1850, are confirmed by the later ones of Mr. W. E. Stevens, United States Consul at Smyrna in 1885.* Mr. Stevens speaks of the ore from three mines as being of nearly equal quality "when well picked and free from unsound ore and waste." He states that it is picked at the mines, in some instances, not one-half being selected, and again picked before shipment. At one place the emery is not much sought after. At another "a great deal of the emery is not mined, owing to the presence of mica in the grain." One ore "is of inferior quality, the grain being smooth and a great deal of magnetic iron entering into its composition." Some of the ore is in its natural state, while some has been subjected to fire, and there are frequent shipments of "inferior or uncleaned stone." Mr. Stevens also states that the abrading power "does not solely depend upon the alumina it contains, but also upon the particular way in which the particles have been placed by nature."

Certain general impressions as to the relative value of different varieties of emery have long influenced the public. A great superiority has been claimed for Naxos emery and a high price is asked for it, but even those skilled in the industry do not seem convinced of its superiority, or, if they admit it, do not consider it a reason for much higher price. Turkey emery is accepted by the general user without any

* *U. S. Consular Reports.* No. 55. August, 1885.

stipulation, except that it be Turkish, though emery mills attach special values to different mines. It appears, however, that no distinctive character really attaches either to Greek or Turkish emery, the quality ranging from first-class to worthless. Good ore is a matter of selection.

This being so, the question arises, what are the chances of getting a well-selected ore? These depend largely on questions of collection, distribution and transport. The unconscious humorist, whose "answer to correspondents" was quoted at the beginning of this lecture, gives one clue. The two Arabs, with a miserable camel, wandering over the back country, and taking or leaving according to size, indicate the crudeness of method and the smallness and great variety of the original finds. He gives another clue when he ascribes the supremacy of Turkey in the emery trade as due to "the cheap, shiftless Arab laborers, who will work for days for a few piasters." Recent progress has somewhat changed matters, for Mr. Stevens says that the Italian overseers and principal workmen get eighty-two cents a day, and the natives about half as much. He speaks of mines opened by wells and galleries, of the free use of gunpowder and dynamite, and of stone being mined at such depth as to require a steam pump. He speaks of the railroad as a means of transport. But it is evident that something of the crude method still survives, and that the railroad station is only a final touch of civilization to a somewhat heathenish course of production; for Mr. Stevens says that "when the mines are situated on heights inaccessible to camels, the ore is brought down to the plains by donkeys. If the pieces are too large to be carried by camels, they are brought to the station in carts drawn by buffaloes." The coast is the ultimate place of collection, and Smyrna seems always to have been the chief port of shipment. In fact, Dr. Smith states that even the emery from the Greek islands went to Smyrna.

It seems clear that emery of the most diverse qualities is gathered in small quantities from many localities, and collected in mass at the coast. From the coast, the places

of consumption are remote, the United States, Great Britain, Germany and France being the principal users. Just as the tutelary commercial deity of Italy has provided it with light weight and bulky rags as an offset to its heavy marble, and so rendered the shipment of both profitable; so had the tutelary commercial deity of Turkey provided emery ore as an offset to its licorice and dried fruits. The result is that emery is shipped, not in accordance with a natural demand in the countries of use, but, according to varying nautical needs, for ballast. After having drifted down from the Turkish mountain tops by donkey, camel and cart—after being lightered from Naxos, Nicaria and other islands to Syra, the masses thus collected begin again to drift away. They pass into the hands of agents, brokers, speculators, shippers and ship-loaders. In lots of 20, 40 and possibly sometimes 100 to 200 tons, they drift, in a sort of irresponsible way, to the docks of London, Liverpool, New York, Boston, etc., where they are handled by brokers, who usually sell by sample. Sometimes the buyer selects at the dock, and some mills make special contracts for special ore. Small lots are frequently offered by brokers, and job lots at low prices are also offered, notwithstanding a fixed general market value. As a rule, the seller has no data to offer concerning quality, and the buyer has to look out for himself. Sometimes he is told the Turkish name of the mine, or is informed that this ore is a new find of some Greek gentleman, independent of the Sultan's concessions and the Greek Government's monopoly, or else he is assured it is exactly the same ore as that which the Wellington Mills professes to monopolize. The real fact is that much emery is unbaptized, unsponsored, unfathered, and the chance of a continuous supply of uniform quality rare in the extreme.

Notwithstanding these variations the average quality of Greek and Turkish emery is such that it finds a steadily increasing sale in the United States, although this country has, for the last five years, furnished an important product.

Our average annual imports of emery ore were:*

	Pounds.
For the decade ending with 1878,	2,376,743
For the decade ending with 1888,	7,315,165
For the five years ending with 1893,	10,705,049

Our average annual imports of emery in grains, ground, pulverized and refined, were:

	Pounds.
For the decade ending with 1878,	621,807
For the decade ending with 1888,	589,054
For the five years ending with 1893,	569,019

The total average annual imports of ore and grain were:

	Tons.
For the decade ending with 1878,	1,338
For the decade ending with 1888,	3,521
For the five years ending with 1893,	5,637

These figures are necessarily incomplete as to 1893, but probably bring down the facts to November.

Side by side with this largely increased importation, is a largely increased native product; for corundum, the average annual output of which, from 1881 to 1888 (both inclusive), was 573 tons (2,000 pounds each), has been supplemented by emery, and the average annual product of the two for the four years ending with 1892, was 2,058 tons.† This gives a total of about 7,700 tons.

While this increased consumption demonstrates the growth of those industries which use emery and corundum, it does not measure the total use of abrasives. Some of the glass works which formerly used emery largely, have given it up and now use silica, while chilled shot and crushed steel have displaced emery to a certain extent among the granite workers. It is worthy of note that the United States Government has, for many years, maintained in its annual report on *Mineral Resources*, a separate department for "abrasive materials." In the Mines and Mining Building, at the Columbian Exposition, abrasives were grouped by themselves.

* United States Treasury Department.

† *Min. Resources of U. S.* 1892. U. S. Geol. Survey, p. 751.

The growing importance of abrasives is such as to suggest inquiry concerning our future supply. At present, we depend, for the larger part of this, on remote foreign lands. Practically on one land, for the emery-bearing Greek islands lie so close to the coast of Asia Minor that they are geographically Turkish and only politically Greek. The ore all passes through a few ports, and the ever unsettled Eastern question might at any time precipitate a war, and the blockade of these ports. The *Encyclopædia Britannica* mentions the occurrence of emery in Sweden, Spain, Saxony and Greenland, but Turkey and Greece are, apparently, the only foreign countries which afford a commercial supply. Thus far our supply of native emery has come from New York and Massachusetts, while the corundum has come from Pennsylvania, North Carolina and Georgia. Some hope of new sources is suggested by the humorist already quoted, who says that emery is "scattered over more or less all the earth," and also by the stream of letters which, for years past, has flowed in upon wheel and emery makers, offering corundum mines from Washington, on our northwest coast, to South Carolina, on the southeast.

[*To be concluded.*]

ENGINEERING PRACTICE AND EDUCATION.*

By Gaetano Lanza, S. B., C. & M. E.,
Professor of Theoretical and Applied Mechanics, Massachusetts Institute of Technology.

If any one among my hearers expects me to begin this lecture by giving a definition of the words *Engineering* and *Engineer*, I am afraid he will be disappointed. Definitions are attempts to describe, or to give the distinguishing characteristics of the thing defined, in a very few words. To give them is comparatively easy when the things defined are of limited scope; but the more extended the scope, the

* A series of six lectures prepared for delivery in the Lowell Institute, in Boston, Mass.; the last three of which were not given on account of the sickness of the Author.

more difficult does it become to circumscribe them within the bounds of a definition.

Indeed, the term *Engineering* has been used with different significations at different times, and what has been its accepted meaning at any one time has depended upon the particular condition of the world's industrial progress at that period.

Without going into a great many details, I may say that the definition of the profession of the *Civil Engineer*, adopted by the Council of the British Institution of Civil Engineers, in 1828, was, "the art of directing the great sources of power in Nature for the use and convenience of man." Such a definition as this is not only vague, but, if taken literally, it would include a range of work far more extensive than that which has ever been or is now understood as the province of the engineer. Nevertheless, the converse is true of the engineer (omitting the limiting term civil), *i. e.*, the engineer must, in the practice of his profession, direct the great sources of power in Nature for the use and convenience of man.

At one time, when the science of engineering was still quite limited in its scope, there were only two designations used, viz.: military engineering and civil engineering, the latter term denoting all engineering which was not military.

Later on, as the science, and hence the scope of engineering, advanced, and as engineers began to devote themselves to special lines of work, there arose a large variety of designations, some of which are: civil engineering (no longer used in the original sense), mechanical engineering, mining engineering, etc., and it was assumed that these professions were quite distinct from each other. Indeed, this idea seemed to be in accord with the natural drift towards specialization, and in the line of progress. Now, however, that the tendency towards specialization is ever on the increase, and that progress has gone farther, I think that any one who will examine the facts carefully, and in a judicial frame of mind, will be satisfied that while all these different kinds of engineers are applying their art to a specialty, nevertheless, the art is one, and the functions

of the engineer comprise one definite, though wide and extensive, range of work.

We will now proceed to consider some examples of the engineering works of the world of different kinds, in such detail as our time will allow; and when we have done this, whether we do or do not attempt to formulate a definition that will describe the functions of the engineer of to-day and of the future, we shall, at any rate, realize and understand better what is the range, what are the kinds, and what is the character of the work which it is the business of the engineer to perform for his fellow-men.

Passing by the pyramids and the works of the Egyptians and of the Eastern nations, it will be worth our while to consider for a short time what was the character of the engineering work of ancient Rome. And, although the development of such work was very different at different periods of the long centuries during which Rome held her sway over the Old World, it will not be necessary for me to trace its various phases, for, inasmuch as the steam engine had not yet been thought of, it was not possible for advances to be made at such a rapid rate as that with which they are developed in our own times. Moreover, a consideration of the engineering work of ancient Rome gives us a conception of that of the whole civilized world as it then existed; for Rome carried her civilization and her engineering everywhere in the wake of her victorious arms.

Indeed, it was very largely to this cause that was due the firm grip that she acquired over the nations that she conquered. They found that their conquerors offered them a civilization more attractive than their own, and that Rome really took an interest in developing their countries, making good roads connecting them with herself, and sending her own engineers to aid them in making other roads and local improvements, besides encouraging them to develop their natural resources. The intimate connection into which they were thus brought with her led them to introduce such improvements as they found that the Romans possessed. Hence we find that Roman roads, Roman bridges, Roman aqueducts and Roman sewers spread to all parts of

Europe, and to all countries which came under her domination. Then when the days of corruption came and when she no longer chose to keep herself in the rank of the producers of the world, but sought to be fed by others without making any adequate return; when she no longer took pains to do thorough work, the Roman example of former times, which had already permeated the other countries of the Empire, still exercised its influence; and hence it is that some of the most lasting and best examples of Roman works were to be found in Gaul, in Spain and in Africa.

When we stop to consider how they managed to accomplish works of such magnitude and of such merit as they did with the small amount of facilities that they possessed, it seems truly wonderful. Imagine for a moment what would be the aspect of the world, and what the material welfare of our own land, if we were to annihilate the use of steam and of all the machinery that depends on steam engines to operate it.

And yet the Romans handled and transported enormous weights, which would even make us stop to consider how best to handle them.

When they had to carry some of their enormous monoliths long distances over land, they encased them in cylindrical wooden boxes, and rolled these boxes along the ground, drawing them by means of a very large number of horses; then, for lifting them, the means they possessed were tackle, rollers, screws and wedges.

Their stone-cutting had to be performed by manual labor, the use of fire and vinegar being only applicable to certain kinds of stone, and even then being hardly ever employed, and no other blasting compounds being known at that time. On their roads, however, were often to be found large numbers of tunnels cut wholly or partially through solid rock; some of their tunnels were of great length, as, for instance, the two tunnels at Posilipo, and also the emissary of Lake Fucino, the latter being a wonderful piece of engineering considering the facilities that they could command, notwithstanding its failure to accomplish its object. Moreover,

they often went so far as to dress the stone on the sides of their tunnels.

The Roman roads I shall not stop to describe, further than to say that, while, from our point of view, they were decidedly narrow, they were built with an amount of solidity that is surprising, and an amount of labor was expended upon them which is very creditable to their makers; moreover, the number and extent of these roads connecting all parts of the Empire with Rome was something enormous for those days.

While they knew and used most of the metals on a small scale, the principal materials employed in their engineering work were stone, bricks and cement, though some of their bridges were built of wood; and of course works of an intentionally temporary character were often constructed of timber.

On account of the difficulties of transportation the materials for building were obtained as near the place where they were to be used as possible; hence, when available, stone was derived from local sources, and this led to the establishment of quarries at a great many places all over the Empire, the quarrying being performed, however, by manual labor, with a very occasional use of fire and vinegar. For their larger works, their bricks were well burned; but the cost of fuel frequently led them to build houses of bricks dried in the sun. Next, as to cement: whenever they could find suitable materials near by, they used them, otherwise they secured it from further off. They had at Pozzuoli, near Naples, however, the source of supply whence they obtained their famous puzzolana, and this was sent wherever needed, being transported by water to the nearest point accessible by that means, and thence by land.

The Roman bridges and viaducts were either of wood or stone. In the case of the latter the full centre arch was almost exclusively used. When they could locate the foundations of their stone bridges on dry land, they built good and solid structures; but when they had to lay their foundations under water, they always had difficulty, and these were generally washed away in a short time, notwithstanding the variety

of expedients to which they had recourse. Hence we find that there were but few Roman bridges across wide streams, where foundations in the river were necessary, but they had no difficulty in crossing deep and narrow gorges where they could establish solid foundations for their work. They had no means of working under water, or of laying foundations under a considerable depth of water, and when they tried they did not succeed to make them sufficiently secure. Their aqueducts and sewers were fine specimens of engineering, considering the facilities they possessed. The water supply from different sources was kept separate, the purest being used for drinking. Their aqueducts were generally made of masonry or concrete, lined with a mixture of cement and brickdust polished smooth.

They carried these aqueducts across gorges or valleys, on stone bridges or viaducts, sometimes built of two or three rows of arches, one above the other, and this method they preferred to the use of siphons, though they had recourse to siphons at times, and, at times they employed a combination of the two methods. They also used settling tanks to clarify the water by allowing the impurities to deposit. Besides masonry conduits, they used lead pipes, but they had no pipes that could bear a very heavy pressure. They had no means of pumping, and hence the water had to be brought to the place where it was to be used by gravity. The sewers were, of course, a necessary consequence of the water supply, and these ran at one time under every street in Rome; but after the reconstruction of the streets by Nero, the lines of the streets did not always follow the lines of the sewers, and hence sewers often passed under the houses. The earlier sewers were constructed of cut stone, and so solidly were they built that the Cloaca Maxima can still be seen to-day, although the greater part of it is filled up with earth. The pitch of the sewers was small, however, and hence they were easily choked up. Moreover, a great many cities in different parts of the Empire were provided with systems of water supply and drainage.

Taking up next the ports and the waterways, we find that,

their boats being small, the works that they needed, and that they therefore executed, would not look large from our modern point of view; but, considering the times, some of them were magnificent pieces of engineering.

As to ports, when they could they built them in a river, erecting quays of stone or wood. They took advantage of the shelter afforded by natural features, and built protecting breakwaters when they needed them.

When they could reach dry land to build upon they always did so, but when not, they sunk large stones, or cradles filled with masonry, locating them by means of divers, or else they built dikes, and ran in liquid concrete, which, on solidifying, formed, as it were, a solid rock.

They had a great many ports all along the Mediterranean. They had, however, no efficient system of dredging, and their ports were always silting up.

Of course, their navigable rivers formed the natural commercial highways, as indeed they did everywhere before the introduction of railroads; hence, they carried out such improvements as they could, and such as were needed at the time, by removing obstructions from the river beds and by building sea walls.

They also built a large number of canals, some to connect two navigable rivers, some to connect a river with the sea, when the character of its mouth was such as to render it difficult for boats to enter in rough weather, and also to drain regions that were liable to be flooded in times of freshets. Apparently they were familiar with the use of sluice-gates, but not with the use of locks. Notwithstanding the fact that they had no efficient system of dredging, the canal built by Claudius and Trajan to connect the Tiber with the sea still forms the present northern branch of the Tiber's delta, although all the works long ago silted up; moreover, it served to provision Rome for four or five centuries. Similar canals were built in the case of a large number of other rivers emptying into the Mediterranean and the Adriatic. Other memorable canals constructed by the ancients were the various ones built from time to time to connect the Nile with the Red Sea, and the one connecting

the port of Alexandria with the Nile, which was planned by Alexander and executed by Ptolemy.

The Romans operated mines, not only in Italy, but also in various portions of the Empire. In Italy itself it is on record that there were gold mines in the valley of the Aosta, that there was galena in Tuscany, iron in Noricum, and that the Etruscans worked iron in Umbria and Brutium. Elba contained iron mines, and does now; and Sardinia, lead mines. A knowledge of mining, however, preceded the times of the Roman conquests, and mining operations were already under way in the conquered countries before the supremacy of Rome, but the Roman sway developed a greater activity in them.

Both Gaul and Spain were rich in mineral resources. The Romans, and also the Greeks, learned the metallurgical processes from the Egyptians and the races of the East. The Romans used gold in its native state, and hence it often contained silver, copper, or even iron. The enormous quantity of copper used by them would seem to indicate that they found native copper, or else carbonate of copper. Throughout France we find traces of old Roman iron works, in piles of slag and cinder, these works being at the mines, in consequence of the difficulties of transportation.

Their condition in regard to manufactures, especially in the earlier days, was so primitive as to be hardly worth speaking of.

Such is a very brief and cursory view of the state of engineering practice among the Romans. While we look with the profoundest respect and admiration at the works which they accomplished with the small means at their command, and while those who executed them deserve the highest meed of praise and all the honor that we can give them, nevertheless I would say to the pessimist who thinks that the world is always going from bad to worse, go and try living with such conveniences as were available in the old Roman times, the narrow streets, the uncomfortable houses, the lack of facilities for travelling, the great lack of conveniences as compared with what we possess to-day, and then see whether you will not appreciate the great boon

that all our modern civilization and industrial progress has conferred upon us.

They possessed nearly all the materials of Nature that we possess, but they had acquired very little control indeed over the great sources of power in Nature, and before they could make much further progress in their engineering work, they needed to be able to direct these for the use and convenience of man. This was what they specially lacked.

With the exception of the wind as used in sailing vessels, they may be said to have used muscular power of men or of animals for the accomplishment of all their work, and their history is a grand example of what man has been able to accomplish by the aid of little else in the way of power than muscular energy; but when they wanted to accomplish a very large task, they had to use a very large amount of this power; thus, in excavating the tunnel under Lake Fucino, it is said that 30,000 workmen were employed for eleven years.

In order to be able to make advances in material prosperity, and to surround himself with a larger supply of comforts and conveniences, man needed something more than muscular energy to aid him in his work. He needed to make the wind, the water, but more especially steam, his servants, and to secure the additional advantages of industrial progress which could never have been realized had it not been for the introduction of the steam engine, before he could pass from such works as those of the Romans to the magnificent engineering achievements of modern times. Indeed, we have in this old Roman work a very good example of what engineering science and enterprise was able to accomplish with practically no aid from machinery; and were I to trace, step by step, the progress of the world only in the kinds of work mentioned, viz., roads, bridges, ports, waterways, water supply and drainage, you would be forced to the conclusion that it was by the introduction of machinery, and of steam power to move that machinery, that every point of vantage was gained, and every advance was rendered possible. By way of illustration, we may note that two of the greatest difficulties which the Romans encountered

were due to not having the means of establishing secure foundations under water, and not having any such means of dredging as we have to-day. I shall not undertake, however, to trace the decadence of engineering practice through the dark ages, nor its subsequent rise, and the gradual steps through which it has reached its present condition, but shall pass at once to a study of engineering practice as it is to-day, and shall try, by means of a sufficient number of examples, covering, as far as may be, the different kinds of engineering work of modern times, to make plain what is the range and what are the characteristics of the work of the engineer to-day.

Probably the thought of engineering in the popular mind has been associated with what are often called Public Works more than with anything else; and especially with the means of transportation of passengers and freight, and hence with the means of facilitating, and, indeed, of rendering possible the commerce of the world, and also with water supply and drainage. These have often been classed as, and have often been, public works; although the fact is that works which have been carried on by the government at one time and in one country have been performed by private enterprise at another time and in another country. Moreover, at the present day the aggregate amount of engineering work demanded by private enterprise is much larger than that required by public works; but there was a time when the reverse was the case, partly because manufacturing and even mining, etc., were in their infancy, and were carried on on so small a scale that there was comparatively little opportunity for the exercise of engineering skill, whereas, public works were executed on a very extensive scale; and partly because, in the case of the old monarchical and despotic governments, it was only the government that was rich enough to carry out large works.

For present purposes, then, we will use the following classification of public works: roads, rail-roads, bridges, canals, improvements of rivers and of estuaries, lighthouses, water supply, drainage, irrigation. It is not my object to enumerate and describe the great works in these different

lines, but merely to make use of a few as illustrations of the character of some of the work of the engineer.

ROADS.

I ought not to pass this subject by without comment, especially in view of the fact that so much general interest is now being awakened in Massachusetts towards having better highways, and I do not doubt that the result of the movement will be that we shall eventually secure them. The very cause that led to the movement, and the movement itself, are added evidences that such work, if it is to be properly done, must be taken in hand by the engineer; and that we shall never have good roads as long as we leave the decision to each man who lives, or each town that is situated on the road, for this means leaving it to men who do not know what are the different methods of making roads, and what are the results that have followed the adoption of any one under certain conditions,—to men, in short, who do not know the experience of the past in that particular line. As to the engineering problems involved in building, maintaining and repairing a road, I shall only say a few words. In building a road there is always a certain amount of cutting and filling that has to be done; then there may be a variety of engineering problems involved according to circumstances. We may have to cut tunnels or half-tunnels in the side of a cliff, though we try to avoid this when we can. Then, if our road runs along the side of a hill or of a mountain, we may have to build stone walls for considerable distances to support the road on the lower side or to protect it on the upper side, and in these cases it is all-important to see that such walls are built properly, and have a secure foundation. We may also have to arrange such works as will carry off the water of any streams that flow down the side of the hill, and to see to it that these works are able to carry off all the water that will come at the time of freshets, so that the road may not be inundated. Along the Alpine roads we find a great many tunnels cut through the cliffs, and while the water that flows down the mountain side often passes downwards through a channel under the road, it sometimes passes over the cliff.

Probably the most important item to be attended to is thorough drainage, and whatever is necessary to secure it should, of course, be done; and the engineer should so construct it that neither the surface nor the subsoil shall retain water. The surface should not have any hollows which will retain water, and should have a slight pitch towards the drains. The engineer must then determine upon the kind of drains—whether they shall be open gutters, or closed conduits, or blind drains, according to circumstances; but whatever they are, they must be of sufficient capacity, and they must be kept open, and not allowed to become choked up; he must also determine where the drains shall deliver the water, and, of course, he must build whatever conduits are necessary. Next comes the construction of the road itself, whether it is to be a paved street or a macadamized road, and, if the first, what kind of paving shall be used; if it is to be macadamized, whether it shall have a paving beneath the metalling. His decision will be influenced by the nature of the subsoil, as well as other circumstances.

He has then to consider the strength and the wearing qualities of the materials that he is to use for paving or metalling. Then also the proper building of the road, including the consolidation of the material by means of the road roller. Then come the questions of what are the repairs that must be made in order to maintain the road in good condition. A great many other matters are liable to require attention, as the curbstones, the catch-basins, the sidewalks, etc. The engineer may have to erect road bridges, and these, of course, involve all the usual problems of designing and erecting bridges, including the proper foundations, etc., but I shall not stop to discuss these at present.

As to the amount of machinery that will be required, this depends upon the nature of the road. In some cases but little is needed, and in other cases a very considerable amount.

RAILROADS.

Let us consider next the engineering work required on our railroads, of which there are about 170,000 miles in the

United States, and which exert so large an influence upon the comfort and happiness of all the inhabitants of our country.

I shall not weary you with the story of George Stephenson's efforts, trials and triumphs when he built the famous *Rocket* for the Liverpool and Manchester Railroad in 1829, a story with which every schoolboy is familiar, but shall proceed to a consideration of what is some of the engineering work that has to be done in building, in equipping and in running a railroad.

We may adopt the following as a convenient classification of the different departments that involve engineering operations, viz.: (1) permanent way; (2) rolling stock; (3) stations; (4) signals; (5) bridges.

Permanent Way.—Beginning with the permanent way, there is first the location of the road, and this involves a very large number of questions that require careful judgment for their solution; of course, it is necessary to take into account primarily the amount of traffic that can be secured by any proposed route; at the same time due regard must be had to the expenses that will have to be incurred, both for first cost and also for operating the line; this, of course, introduces a consideration of the grades that will have to be surmounted, the curves that will have to be tolerated, the bridges that will have to be built, the excavations that will have to be made, the difficulties that are liable to present themselves in keeping the road in repair, sometimes the difficulties to be met with to keep it clear of snow, and a host of other considerations; then the actual work to be done in making the surveys, and fixing the location in a new country may involve a good deal of work, and a rather rough-and-tumble life. In America, instead of building the road up to the standard we should desire at the start, it is much more customary to build it poorly at first, and then make improvements as fast as money is earned with which to make them. So, in the first building of the road, the engineer may, to save expense, allow steeper grades and sharper curves than would perhaps be necessary if a little more expense were incurred, with the idea that

after the line has been in operation for a while, and has earned a sufficient amount of money to warrant it, the curves can be straightened out and the grades reduced; but he must see beforehand how this can be done. Leaving to one side for the present the matter of the bridges, we will assume that the road is located, and the permanent way is to be built. We have now, to a certain extent, a set of questions similar to those that arise in the case of common roads. There will be, of course, a great deal of cutting and filling. For taking out heavy cuttings we use steam shovels, one of which can do the work of 500 men, and when the embankment is made from earth thrown up from ditches on each side, ditching machines are used, some of which can throw up 3,000 cubic yards per day. In this case, just as in the case of a common road, we must see to it that the roadbed is thoroughly drained, and now, after the roadbed is made, we must put on a good layer of ballast of broken stone. This is the best, for it does not hold moisture. Moreover, that the ballast should be hard and well packed and should not hold moisture, are considerations of prime importance. On top of this ballast are placed the sleepers, which are carefully laid at the proper distance apart, and are so adjusted as to have an even bearing on the ballast; then their upper surfaces are dressed and the rails are laid down; then the roadbed is covered with gravel, which should be up to the tops of the sleepers, and then the chairs are placed and the rails are spiked down. Then the upper ballast or gravel is tamped in under the sleepers so as to cause them to have so thorough a bearing that they will receive the pressure of the rail equally. Now, besides the bridges on the road, there are a good many culverts, or small bridges that have to be built, where water drains off, and for other reasons. When they are to be permanent they are usually built of stone, but very often temporary ones are built of trestle work, and this is often supported on piles. Hence, we have use, so far, for steam shovels, ditching machines, pile drivers, and sometimes steam dredgers. Next, as to the rails; their weight has gradually increased from thirty-five pounds in the days of George Stephenson, to eighty, ninety and even 100 pounds

per yard at the present day. Moreover, while the first rails used were of wood, those of George Stephenson were of wrought iron, but now they are almost exclusively made of Bessemer or open-hearth steel; and this increase in the weight and the strength of the rails has been brought about of necessity in consequence of the increase in the weights of the locomotives from five or six tons for engines like the Rocket to fifty tons and more to-day. Another matter which the builder of a road in a settled country is liable to have to consider is the works needed to avoid grade crossings. Then in regard to tunnels, the American locomotive is so constructed that it can go around much sharper curves than the English or the European locomotive, and hence we can avoid tunnels much more easily than we otherwise could.

After the permanent way is established it requires constant and careful attention, as a variety of unforeseen accidents are liable to happen. Washouts may carry off bridges or culverts, wooden trestles may rot or take fire, rails may break, chairs may break or get loose, spikes may come out, landslides may occur in mountainous regions, obstructions may get on the track, collisions or accidents may occur. All these things must be guarded against by a most careful inspection, and when anything is found out of order, it should be repaired at once.

Then another matter that devolves on the inspection and repair gang is the following, viz.: the road, and hence the rail, is liable, through unequal settlement, to acquire an uneven upper surface, this occurring most frequently at the joints, and then not only is the riding made uncomfortable, but also there is more power required to draw the train than would be the case if the surface were even. Hence, it is a matter of importance, from the point of view of economy, to keep the roadbed in first-class condition.

Some roads have a dynamometer car which is primarily a car containing mechanism by which we can obtain a record of the pull on the draw-bar at any given instant, or for any given position of the train on the road. These cars are usually provided with another mechanism, which, whenever the car passes a hollow in the track, throws a little

paint on the side of the rail near the place. When a road has one of these dynamometer cars it generally uses it for this purpose, and then the trackmen find the paint and proceed to level up the track at that place. If it does not have a dynamometer car of its own, it often hires some one who has, to make the inspection. All these things require a large force to keep the permanent way in order, and it needs to be inspected constantly in all its parts. When, however, there is a break-down, it is often easier to bring men and material from some distant central depot than to try to get along with such appliances as can be found near by. It may be well to say that on our railroads there have been, and are still to be found, a large number of timber bridges, and that, doubtless, in the earlier days of the country, it would not have been possible for the roads to afford the money to build iron bridges; but that now steel bridges are the rule, and while timber is still used for temporary work, its use for permanent work in the way of railroad bridges is fast dying out.

Rolling Stock.—We next come to the rolling stock. As soon as the road becomes of considerable magnitude, the works connected with it have to be very extensive, and require a large amount of engineering work. One might imagine that when once the rolling stock is all purchased, if the road is small and not growing, and if the shops and buildings for the housing and the repair of the rolling stock are all built and equipped and in operation, that the looking after everything to keep it in proper order and repair, and the purchasing of the supplies needed, as coal, oil, etc., while it would involve the exercise of considerable executive ability, need not involve any considerable amount of engineering work; but as any one who carries on such work knows very well, the management of a business where so large an amount of machinery is concerned, necessarily involves a large number of engineering problems.

As examples, shops have to be enlarged or new ones built; new and improved or more powerful machinery has to be introduced, which may involve various rearrangements; alterations in some of the details of the running gear or

of some other portions of locomotives or cars; the providing of additional space for receiving coal, and of suitable arrangements and facilities for delivering it where needed; making suitable arrangements for keeping cars at such places as are needed on the road, so as to have them ready when and where they are needed; the establishing the necessary yards with the proper tracks and switches; establishing the necessary stationary boilers, pipes, etc., to heat the cars before starting; then comes the care of and the running of the shops, for any railroad, no matter how small, must have at least a repair shop, and, as in such a repair shop, the road must be prepared to make anew a considerable number of the parts of the locomotives and cars, the question always arises how far to go in manufacturing the parts new, and then how far to go in the matter of building, in whole or in part, new locomotives, and hence will arise all degrees of development in this regard, up to the point where the road manufactures all its own rolling stock, involving, in that case, a very large amount of engineering work.

Another matter that becomes of importance, as soon as the road is able to afford such a department, is a department of tests. This department usually has charge of tests of all kinds, including, of course, tests of oils and tests of the strength of materials, and any other tests which it may be deemed best for the road to make.

Thus, suppose that the road is considering the advisability of adopting some new kind of locomotive for a certain kind of service, and desires to know whether the change is liable to result in economy, especially in saving coal or not, it may be wise to have a series of comparative or even of absolute tests made to determine either its relative or its actual performance in regard to coal and water consumption. Or suppose the road is considering the advisability of making some change in the details of its locomotives or cars, and wishes to determine the effect of the change, as, for instance, in the brake gear, or in the manner of heating the cars, or in some arrangement for ventilating them, all such matters would come to the test department; besides

which, if the road is large, there will be enough chemical tests to keep at least one chemist busy, as tests of oils, of paints and varnishes, chemical tests of the materials used, etc. Then, of course, if new shops are to be built and equipped, there arises a variety of problems, first in regard to the foundations of the buildings, then as to the details of the buildings, their proper strength, heating, ventilation, light and adaptability to their purpose; their arrangement so as to require as little handling of the material as possible; the choice of the machinery to be used; its arrangement; whether there shall be much special machinery, and if so, what; the power plant; what kind of engines will be best to use under the circumstances of the case; how many there shall be, and where located; the laying out of the entire system of driving, including shafts, pulleys and belting or other modes of driving, if they are to be used; the steam boilers to be used; the erection of a suitable boiler house and chimney and its location; the foundry; the forge shop and its equipment, possibly including heavy steam hammers; the boiler shop, with all the necessary machinery, as plate-shearing, bending and planing machines, punching and drilling machines, hydraulic, steam or compressed air riveters, etc., besides the necessary cranes, etc., for handling the boilers in process of construction, as well as the establishing of suitable cranes or trolleys for handling the materials in all the shops in the best and easiest manner; the carpenter shop; the erecting shop for the locomotives. In the case of a number of large locomotive works, cranes are provided which can lift the entire locomotive and carry it from one part of the shop to another.

Then there is the building of the transfer tables, the building of the cars, with all the necessary appliances of brake pipes, heating pipes, lamps, couplers, seats, etc., the painting and varnishing of the cars and upholstering them, etc.

Then, in the case of very large railroad shops, the road might decide to make and roll its own steel, which would, of course, involve a complete furnace plant and rolling mill.

This course is followed by the London and Northwestern Railroad at Crewe, England, where they have a Bessemer plant with four converters, each of which is capable of turning out five tons of steel at one heat. The pig iron, which they buy elsewhere, is melted in a cupola furnace, and the melted metal is then carried by means of large ladles to the converters, which are vessels that can be turned over on their sides and back to an erect position, as they are mounted on trunnions. The converter is turned on its side, and the melted pig iron is poured from the ladle into the converter. Then a powerful blast is introduced, and the converter is turned back to an upright position, when combustion goes on violently, the oxygen of the air burning out the carbon of the pig iron. When this combustion has gone on for a suitable length of time, usually fifteen or twenty minutes, a determined amount of spiegeleisen, *i. e.*, an iron rich in carbon and in manganese, is mixed with the melted mass; then the converter is turned on its trunnions, and the liquid steel is poured into a ladle, whence it is run into the cast-iron ingot moulds, and is thus formed into ingots.

They also have an open hearth plant, with seven Siemens-Martin furnaces, *i. e.*, five twenty-ton, and two ten-ton furnaces. These are, of course, regenerative furnaces where the gas is made in gas producers situated elsewhere, and is brought to the furnaces through pipes laid under the ground. Then the gas on its passage to the furnace passes through a red-hot checkerwork of firebrick, while the blast is introduced after passing through another red-hot checkerwork; the combustion takes place in the furnace, where are placed the pig, the scrap, and other materials required; and then, as the air and gas meet at a high temperature, combustion occurs and the carbon is burnt out of the melted mass; then the hot gases pass out through two other checkerwork chambers to the chimney, thus heating up these chambers, so that the gas and air can be made to enter through them when the other two have become too cool. They have a rail-making plant of 45,000 tons annual capacity, and also a mill for making tires for locomotives and car wheels; a mill for mak-

ing plates, and a mill for making merchant bars and other shapes which they may require. The steel from these rolling mills is then carried to the other shops, where it is to be used, on cars drawn by a small locomotive on a narrow gauge railroad which goes to all parts of the works.

It may be well to say a little more about these enormous works at Crewe, where the London and Northwestern Railroad can start from the raw material and make all parts of its locomotives and other machinery, except copper plates and brass tubes. These works not only make locomotives, but also all the signalling apparatus, and the signal cabins themselves, also cranes and other machinery, and even bricks, drain pipes, and also gas, besides which they have their own water works. The total area enclosed by the works is one hundred and sixteen acres, whereas the buildings cover thirty-six acres.

Of course, the shops where the locomotives are manufactured and repaired contain an enormous amount of machinery, and among the rest a considerable amount of special machinery. The steel plant is capable of turning out 5,000 tons of steel a year, and the total number of locomotives that have been made there up to May, 1890, was 3,135.

The greater portion of the parts of the locomotives of a given class which they build there are interchangeable, being made to standard sizes; so that if in an accident almost any one part of an engine is broken, another can be found in stock which will be suitable to put in its place and which will fit at once. There are about 6,500 men employed at these works, where about 2,000 engines a year are repaired, and where as many as 146 have been made in one year.

To establish and keep up this enormous place it has been necessary for the road to make provision for enabling its workmen to live there, as the town has practically been built up by the railroad. The company own about 850 houses, and they have built at their own expense a Mechanics' Institute and a church, and they have done a great deal to furnish to their employés and their families opportunities for improvement and amusement.

The cars are not made at Crewe, but at Wolverton, where

the works cover about fifty acres, and where they employ 2,200 workmen, and where they buy the wood in the form of logs, and again they have a narrow gauge railroad running to all parts of the works, and cranes of all sorts, so as to be able to handle the material and the work easily. The timber is sawed into planks or whatever form may be desired here, and then it is put into a drying room and seasoned, before it is used in building cars. The wheels are also made at Wolverton, these being wood wheels with steel tires, the wood being forced into the tires by hydraulic machinery. Then, of course, there is done here all the upholstering, painting, varnishing, etc. When we consider the extent and magnitude of these works, it is evident that there is the necessity for a very large amount of purely engineering work. The putting up of the buildings alone involves questions of adaptation of the arrangement to the greatest economy in handling, consistent with efficient working; adaptation of the form and proportions to the work to be done in them; questions of suitable foundations; questions of light; questions of strength of materials, especially considering the heavy loads that have to be borne in some of them; questions of chimney power, and of foundations for and stability of chimneys, of draught of chimneys, etc. Then besides this the road has to do all the engineering work for a large town and has to make provisions for a great deal that usually belongs to the town to provide, and not to a railroad corporation, thus it has to supply the town with water and gas, and all this means water works and gas works, and the solution of engineering problems that arise in connection with them.

Then it has not only to build its own shops but also houses in the town, hence it has to make brick.

Then in order to make all the saving possible in labor, there is required a large amount of special machinery, and to design such, a man needs to be familiar with mechanism, and with the design of machinery, including questions as to its strength, its stiffness, and its proportions generally, as for instance, its bearing surfaces, etc.

Then need I say that the steam plant needs attention?

Are the engines and boilers, and their arrangement and running such as will ensure the greatest economy? Also the amount of coal and iron and other materials brought into these works must be something enormous, hence means must be provided for receiving them, for unloading them, and for storing them until they are needed.

Then, besides all these questions which involve a knowledge of mechanism, of strength of materials, and of steam engineering, etc., we have use for electricity in various ways. The first to present itself to one's mind in connection with a railroad will naturally be the signalling; but there are also other connections in which, if it is not much used yet, I do not doubt it will be ere long, viz: electric lighting, not only for the shops, but also for the cars, for although electric lighting of steam cars has not thus far progressed to the point where it is at all rivalling or likely to rival for some time the methods of lighting by gas or by oil; nevertheless, I believe that in course of time more progress will be made in this direction, and then we shall come to have our steam cars lighted by electricity; also in the use of electric brakes, which at present are employed only to a small extent; also in the use of electric cranes, which are the modern form of crane without any question. Indeed, electricity is gradually displacing other methods of driving cranes in our large shops and rolling mills and bridge works. By using it we avoid a great many clumsy methods of transmitting power, for the power has to be applied in such a way that the crane can be driven wherever it stands in its travel. An electric motor carried by the crane itself, with the connecting wires, furnishes an easy and neat method of transmission, and does not involve so much loss by friction. The application of electric motors to cranes will, in my opinion, be extended to a large extent to other machinery in our large machine shops and manufactories, and I believe it will not be many years before electric transmission of power will displace a great deal of the shafting and belting with which our shops are so much filled up at present.

Besides all this we have opportunities and the necessity

for a large amount of engineering knowledge and engineering work in the design and construction of the locomotive itself.

What are the conditions which we wish our locomotives to fulfill? They are to draw our trains at as high a speed as is consistent with safety, and to do this with the least expenditure for coal, for water, for repairs, etc., also to fulfill all the special conditions of the particular service which they are to perform, such as going around sharp curves, going up steep grades, hauling heavy trains, etc.

Of course, it is necessary that they should have the requisite strength and stiffness. Now, we have here at once questions of mechanism, questions of strength of materials, and questions of steam engine economy.

[*To be continued.*]

NOTE ON PEMBERTON'S METHOD OF PHOSPHORIC ACID DETERMINATION AS COMPARED WITH THE OFFICIAL METHODS.*

By Wm. C. Day and A. P. Bryant.

Having occasion to make a series of determinations of phosphoric acid in Florida phosphate rock, we have used the method recently described by Mr. H. Pemberton, Jr.,† and incidentally have made a number of comparisons between it and the official method. The following are the results:

GRAVIMETRIC DETERMINATIONS.

No. 1. From 0·7867 grms. $Na_2HPO_4 + 12H_2O$, obtained 0·2426 grms. $Mg_2P_2O_7$
No. 1. From 1·1100 grms. $Na_2HPO_4 + 12H_2O$, obtained 0·3433 grms. $Mg_2P_2O_7$
No. 2. From 1·0000 grams Florida rock, obtained 0·5828 grams $Mg_2P_2O_7$
No. 3. From 0·3807 grams Florida rock, obtained 0·0262 grams $Mg_2P_2O_7$
No. 3. From 0·4831 grams Florida rock, obtained 0·0333 grams $Mg_2P_2O_7$
No. 4. From 1·0036 grams Florida rock, obtained 0·0227 grams $Mg_2P_2O_7$

* Read at the stated meeting of the Chemical Section, held February 20, 1894.

† *Jour. Frank. Inst.*, **136**, 362.

DETERMINATIONS BY PEMBERTON'S METHOD.

No. 1 used 1·0737 grams $Na_2HPO_4 + 12H_2O$ and 22·80 cubic centimeters KOH solution and 1·85 cubic centimeters acid.

No. 1 used 1·0370 grams $Na_2HPO_4 + 12H_2O$ and 21·30 cubic centimeters KOH solution and 0·80 cubic centimeter acid.

No. 2 used 1·0000 grams Florida rock and 41·85 cubic centimeters KOH and 5·05 cubic centimeters acid.

No. 3 used 1·0000 grams Florida rock and 7·55 cubic centimeters KOH and 3·10 cubic centimeters acid.

No. 4 used 1·0000 Florida rock and 6·75 cubic centimeters KOH and 5·50 cubic centimeters acid.

Strength of H_2SO_4 used 1 cubic centimeter = 0·015998 grams H_2SO_4.

Strength of potassium hydrate solution 1 cubic centimeter = 0·01847 KOH.

The percentages of P_2O_5, calculated from the foregoing determinations, are:

Substance.	*Gravimetric.*	*Pemberton.*
No. 1, sodium hydrogen phosphate, ...	19·72	19·73
No. 1, sodium hydrogen phosphate, ...	19·78	19·99
No. 2, Florida rock, ...	37·28	37·22
No. 3, Florida rock, ...	4·40	4·53
No. 3, Florida rock, ...	4·41	—
No. 4, Florida rock, ...	1·45	1·32

It is evident from the above figures that the agreement between the results of the two methods is as close as could be desired. Inasmuch as the Pemberton method is of extreme accuracy, is very easily carried out and effects a great saving of time and labor over the official method, it is well worthy of extended use. We have found that the author's statement of the time required for a single determination, namely, thirty to forty minutes from the time the solution is measured out for titration, is entirely reasonable. Omitting filtration of silica makes no difference in the accuracy of the results.

SWARTHMORE COLLEGE, PA.,
February 20, 1894.

BOOK NOTICES.

Encyclopèdie Scientifique des Aide-Mémoire. Dirigée par M. Léaute, membre de l'Institut. Paris: Gauthier-Villars et fils et G. Masson. Collection de 300 volumes petit in-8. Chaque volume se vend séparément; broché 2 fr. 50; cartonné, 3 fcs.

Of this capital publication, which has received several previous notices in the *Journal*, we have received the following additional volumes of the series:

Bloch, Frédéric. Ingénieur des Manufactures de l'État. *Eau sous pression. Appareils producteurs d'eau sous pression.*

Launay (de). *Statistique de la production des gîtes métallifères.*

Widmann. Directeur général des Forges et Chantiers. *Principes de la machine à vapeur.*

Croneau, A. Ingénieur des Constructions navales, Professeur à l'École d'application du Génie maritime. *Construction du Navire.*

Gérard Lavergne. Ancien Elève de l'École Polytechnique, Ingénieur civil des Mines. *Les Turbines.*

Minel, P. Ingénieur des Constructions navales. *Introduction à l'Électricité industrielle. Potentiel. Flux de force. Grandeurs électriques.*

Minel, P. Ingénieur des Constructions navales. *Introduction à l'Électricité industrielle. Circuit magnètique. Induction Machines.*

We have nothing to add to our earlier favorable notice of this series, save the announcement that the later volumes fully bear out the fair promise of their predecessors. The fact that each of these volumes is complete in itself, constituting a concise summary of the state of the science or the art on which it bears, should make the series extremely popular. W.

Engineering Education Being the proceedings of Section E of the World's Engineering Congress, held in Chicago, July 31st to August 5, 1893. Published by the Society for the Promotion of Engineering Education, as Vol. I of their Proceedings. Edited by De Volson Wood, Ira O. Baker, J. B. Johnson, Committee, Columbia, Mo. E. W. Stevens, Printer. 1894.

This volume contains a portion of the papers read and discussed before Division E (Engineering Education) of the World's Engineering Congress, held in Chicago during the period of the World's Fair. The participants comprised many of the leading instructors in the engineering branches in the technical schools of the United States, and the themes presented and discussed were such as would properly suggest themselves to a body of professional teachers interested in the advancement of the standard of engineering education in our country. The papers may be read with much profit by all who are interested in technical education, and afford excellent evidence of the rapid progress made in this direction in recent years. W.

Les Moteurs à Gaz et à Pétrole. Par M. Gustave Richard, Ingénieur civil des Mines, etc. Paris: Vve. Ch. Dunod, Editeur, 49 Quai des Augustins. 1892.

The volume above entitled constitutes an exhaustive monograph on the subject of gas and petroleum engines, which mechanical engineers and others desiring access to a work going thoroughly into the questions of the theory and practice of this type of motor, should find of inestimable value. The work is issued in three parts, with an atlas of plates. The text also is profusely illustrated. The atlas, giving excellent sectional views of every important engine in this class, is incomparably better than anything yet published in the English language. W.

Sewage Purification in America. A description of the Municipal sewage purification plants in the United States and Canada. By M. M. Baker. With seventy-nine illustrations and an index. New York: *Engineering News* Publishing Company. 1893.

This volume is composed of a series of articles which originally appeared in the *Engineering News*, revised and classified for publication in book-form.

The subject is one of the first importance, and is attracting more and more attention every year from municipal authorities.

The literature relating to the subject could only be consulted heretofore by searching laboriously through municipal and other official reports, and the technical journals, widely scattered and difficult of access through the public libraries. The publishers of this series of papers, therefore, have done a real service to the engineering fraternity by collecting under one cover the more important data relating to the experience gained in sewage purification from the practice of some thirty municipalities in this country. W.

Journal of the Association of Engineering Societies. Vol. XIII, No. 1, January, 1894. Published monthly by the Board of Managers of the Association of Engineering Societies. John C. Trautwine, Jr., Secretary, Philadelphia. $3.00 per year, 30 cents per number.

The January impression of the Journal of the Association of Engineering Societies comes to us in a new dress, and exhibits other external and visible signs of improvement. Although the general features of internal arrangement have suffered no substantial change, evidences of careful and judicious editorial supervision are very apparent, as the result of Mr. Trautwine's painstaking and conscientious work. The co-operative feature of the Journal is a capital one, and is worth consideration by societies or associations having kindred objects, and which are individually not strong enough to maintain the cost of an independent publication. By co-operation this obstacle could readily be overcome and each would help the others while reaping the benefit of the work of all. The success of the publication of this Association, in this respect, is a conspicuous example of the benefit to be derived in this way. The Association is composed of the Engineering Societies of Boston, Chicago, Cleveland, Kansas City, Minneapolis, Montana, St. Louis, St. Paul and Wisconsin. W.

"*The Iron Founder*" *Supplement:* A complete illustrated exposition of the art of casting in iron, etc. By Simpson Bolland. Illustrated with over 200 engravings. First edition. 400 pp., 12mo. Cloth. $2.50. New York: John Wiley & Sons. 1893.

This volume is designed to supplement "The Iron Founder" of the same author, published several years ago, and which has had a cordial reception among those for whom it was written. "The Iron Founder" was devoted specially to the manipulations related directly to the daily practice of the moulder's art. The Supplement deals with matters bearing only indirectly on the work of the moulder, but which, nevertheless, it is to his advantage to know. The subjects treated of in the present volume embrace such matters as the erection and management of cupolas, reverberatory furnaces, blowers, dams, ladles, etc.; mixing cast iron; founding of chilled car wheels; malleable iron castings; foundry equipments and appliances; gear moulding machines; moulding machines; burning, chilling, softening; annealing; pouring and feeding; foundry materials; advanced moulding; measurement of castings; wrought iron, steel; the founding of statues, the art of taking casts, pattern modelling, etc.

From the foregoing summary, a fair idea will be obtained of the contents. The book is thoroughly practical in treatment, and will readily be comprehended by the foundry operative, to whom it is primarily addressed. The illustrations are numerous and most of them specially prepared for the book.

W.

Gas Lighting and Gas Fitting; including specifications and rules for gas piping, notes on the advantages of gas for cooking and heating, and useful hints to gas consumers. Second edition, rewritten and enlarged. By Wm. Paul Gerhard, C. E. New York: D. Van Nostrand Company, 23 Murray and 27 Warren Streets. 1894. Price, 50 cents.

This is the second edition of a very useful hand-book, forming No. 111 of the *Van Nostrand Science Series.* It is designed specially as a handy reference book for gas engineers, gas fitters, manufacturers of gas fixtures, dealers in gas appliances. Incidentally, it contains much information of a practical nature for gas consumers, architects and builders. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, April 18, 1894*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 18, 1894

MR. HENRY R. HEYL in the chair.

Present, sixty-five members and twelve visitors.

Additions to membership since last report, fifteen.

The Secretary announced the death of Mr. John Howard Gibson, a member of the Board of Managers, and reported that at its stated meeting, held on Wednesday, April 11th, the Board had taken suitable action in relation thereto, and had appointed a committee to prepare a memoir of the deceased for publication in the *Journal*. The Chairman, after an appropriate allusion to the loss which the Institute had sustained in the untimely death of one of its most active managers, directed that an election be held to fill the vacancy thus created in the Board.

The election resulted in the choice of Mr. Thomas P. Conard.

Mr. Clayton Beadle, of London, England, presented a paper describing some interesting newly-discovered cellulose derivatives, and products obtained therefrom, by methods devised and patented by Messrs. Cross, Bevan & Beadle, of London. Mr. A. D. Little, of Boston, supplemented the remarks of the previous speaker by giving an account of the properties of these products and of the various uses for which they were found adapted. The material, according to the manner of manipulating it, makes an excellent adhesive, taking the place of glue; it can be applied advantageously as a sizing in the manufacture of paper, in cotton goods, etc.; in massive form it can be moulded, pressed, turned, sawed, etc., and applied to the multifarious uses of hard rubber, vulcanized fibre, celluloid and similar products. It can be rolled into the form of plates or sheets of extreme thinness, the latter being almost transparent. It is capable of accepting various dyes, and of being mingled with mineral and other pigments. In these forms, the material may be made, by proper manipulation, to serve as floor covering, or leather substitute for bookbinders' and upholsterers' uses, etc.

A large number of specimens were shown, exhibiting various forms of these products and their applications.

Mr. F. E. Ives gave an interesting account of recent progress in the field of color photography, and described and exhibited the improved form of his photo-chromoscope, and a simple method of projecting photographic images on the screen in the colors of nature with the ordinary stereopticon.

The Secretary's report embraced a reference to the subject of the corrosion of gas and water pipes and underground electric cables from the effects of leakage of the return current of the electric trolley lines. The trouble

from this cause, the Secretary remarked, had grown to serious proportions in certain cities where the surface electric roads had been for some time in operation, notably in Brooklyn and Boston. He presented some extracts from a special report on the subject that had been made by the "Board of Commissioners of Electrical Subways" in Brooklyn, illustrating the same by the projection on the screen of views of a number of telephone cables, water and gas pipes, which had been dug up in Brooklyn, and all of which exhibited evidences of extensive corrosion, ranging from superficial pitting to complete perforation.

The Secretary gave a brief summary of the recent investigations of Dr. Engler upon the origin of petroleum. Dr. Engler had succeeded, by subjecting animal fats and fatty acids to distillation under high pressures, in converting about seventy per cent. of these products into petroleum hydrocarbons, obtaining in the operation ninety per cent. of the theoretical yield. These experiments appeared to demonstrate that the origin of petroleum is to be sought for in the transformation of the fatty portions of the animal remains abundantly found in the rock formations, in, or contiguous to which, petroleum occurs.

The Secretary described and exhibited the Falconnier blown-glass bricks, which have been used with very satisfactory results in the construction of conservatories, greenhouses, etc. These bricks are hollow and are blown in various shapes, and principally with ribbed or corrugated exteriors. They are very light and strong, and when laid together present an ornamental appearance. They permit of the transmission of an abundance of light; their corrugations serve to scatter the light and to avoid its concentration. They are hermetically sealed while hot, thereby preventing the entrance into them of dirt or moisture, and are annealed to increase their power of resistance. The laying of these bricks is said to be plain bricklayer's work, interposing no difficulties. The vaults are built up over a wooden centre, and the joints are made with lime mortar, or light cement mixed with fine sand.

Adjourned.

WM. H. WAHL, *Secretary*.

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, L. F. O. IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR MARCH, 1894.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 31, 1894.

GENERAL REVIEW.

March's normal temperature and rainfall is about 35°.0 and 3.57 inches. The present month has been 8°.2 warmer than the average, and the rainfall 1.94 less.

The warmest days were the 6th, 18th and 22d, and the coldest 1st, 26th, 27th and 28th. The lowest temperature recorded was Saegerstown, minus 2° on the 28th.

There was a deficiency of 1.94 of precipitation. The rainfall was quite evenly distributed and occurred at short intervals. The snowfall was light, and only one station reported any on ground at end of month.

A brilliant auroral display occurred on the 30th.

This issue completes the publication of the series of charts showing by isothermal lines the normal temperature of each month of the year.

From January 1, 1894, to March 31, 1894, the excess in temperature at Philadelphia was 315°; Pittsburgh, 416°; and Erie, 357°.

For the same period the deficiency in precipitation at Philadelphia was 3.45; Erie, 2.31; and Pittsburgh, 1.40.

TEMPERATURE.

	Mean Temperature.	Mean Precipitation, Inches.
March, 1888,	31°·1	3·55
1889,	38°·9	2·90
1890,	33°·4	5·15
1891,	34°·1	5·10
1892,	32°·0	4·14
1893,	34°·7	2·52
1894,	43°·2	1·63

The means of the daily maximum and minimum temperatures, 53°·8 and 32°·5, give a monthly mean of 43°·2, which is about 8°·2 above the normal, and 8°·5 above the corresponding month of 1893.

The average daily range was 21°·3.

Highest monthly mean, 49°·4 at Altoona.

Lowest monthly mean, 37°·5 at Honesdale.

Highest temperature recorded during the month, 84° on the 22d at Logania.

Lowest temperature, minus 2° on the 28th at Saegerstown.

Greatest local monthly range, 77° at Saegerstown.

Least local monthly range, 50° at Altoona.

Greatest daily range, 48° at Ligonier.

BAROMETER.

The mean pressure for the month, 30·10, is about ·08 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·62 at Philadelphia on the 28th, and the lowest 29·63 at Philadelphia and Harrisburg on the 13th.

PRECIPITATION.

The average rainfall, 1·63 inches for the month, is a deficiency of 1·94.

The largest monthly totals in inches were Uniontown, 2·90; Davis Island Dam, 2·64; Mahoning, 2·55; Blue Knob, 2·49, and Pittsburgh, 2·41.

The least were Wellsboro, 0·24; Altoona, 0·80; South Eaton, 0·80; Lock Haven, 0·84; Le Roy, 1·00, and Kilmer, 1·03.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 8; clear days, 12; fair days, 11; cloudy days, 8.

MISCELLANEOUS PHENOMENA.

Thunder.—Blue Knob, 13th, 15th, 23d, 31st; Hollidaysburg, 15th, 22d; Quakertown, 13th, 22d; Johnstown, 1st, 2d; Emporium, 15th; State College, 15th; West Chester, 23d; Kennett Square, 23d; Phœnixville, 22d; Westtown, 22d; Bloomsburg, 13th; Saegerstown, 15th; Carlisle, 22d; Harrisburg, 15th, 26th; Swarthmore, 6th, 23d; Uniontown, 15th, 22d; Hunting-

don, 15th, 22d; Kilmer, 22d; Lancaster, 22d; Lebanon, 22d; Coopersburg, 13th, 15th, 22d; Logania, 15th, 22d; *Philadelphia* [Weather Bureau], 23d; [Centennial Avenue], 23d; [Locust Street], 22d, 23d; Wellsboro, 13th, 15th, 21st, 22d; Lewisburg, 15th; Dyberry, 2d; Hamilton, 2d; Ligonier, 15th, 22d; York, 15th.

Hail.—Blue Knob, 15th; Johnstown, 15th; Emporium, 15th; Phœnixville, 15th; Carlisle, 15th; Somerset, 13th, 15th; Wellsboro, 15th; Hamilton, 2d; York, 15th.

Snow.—Blue Knob, 26th, 27th; Hollidaysburg, 26th, 27th, 28th; Le Roy, 15th, 25th, 26th, 27th; Emporium, 15th, 29th; State College, 15th; Grampian, 15th, 26th, 29th; Lock Haven, 15th; Uniontown, 25th; Wilkes-Barre, 15th; *Philadelphia* [Centennial Ave.], 15th, 26th, 27th; Selins Grove, 15th.

Sleet.—Blue Knob, 15th; Hollidaysburg, 15th; Quakertown, 15th; Johnstown, 15th; Emporium, 15th; State College, 15th; Grampian, 15th; Lock Haven, 6th, 15th; Kilmer, 15th; Coopersburg, 15th; Wilkes-Barre, 15th; Kane, 15th; Greenville, 15th; Logania, 15th; *Philadelphia* [Centennial Avenue], 15th; Honesdale, 15th; Ligonier, 15th, 22d.

Aurora.—Blue Knob, 31st; Le Roy, 30th; Quakertown, 30th; Johnstown, 29th; Emporium, 30th; Mauch Chunk, 30th; State College, 30th; West Chester, 30th; Coatesville, 30th; Kennett Square, 30th; Phœnixville, 30th; Westtown, 30th; Grampian, 30th; Lock Haven, 30th; Bloomsburg, 30th; Saegerstown, 30th; Carlisle, 30th; Harrisburg, 30th; Edinboro, 30th; Chambersburg, 30th; Kilmer, 30th; Lancaster, 30th; Lebanon, 30th; Coopersburg, 30th; Kane, 30th; Greenville, 30th; Pottstown, 30th; Logania, 30th; *Philadelphia* [Weather Bureau], 30th; [Centennial Avenue], 30th; Shingle House, 30th; Selins Grove, 30th; Somerset, 30th; Wellsboro, 30th; Dyberry, 30th; Honesdale, 30th; Hamilton, 30th; Ligonier, 30th; South Eaton, 30th; York, 31st.

Coronæ.—Blue Knob, 18th; *Philadelphia*, [Locust Street], 19th, 20th; York, 31st.

Solar Halo.—Le Roy, 6th, 10th, 30th; *Philadelphia* [Weather Bureau], 9th, 12th, 15th, 20th, 28th; [Centennial Avenue], 12th, 13th, 15th, 20th, 28th; Selins Grove, 28th.

Lunar Halo.—Blue Knob, 12th, 17th; Emporium, 12th; State College, 19th, 21st; Lancaster, 17th, 18th; *Philadelphia* [Weather Bureau], 17th; [Centennial Avenue], 17th; Shingle House, 22d.

Parhelia.—Lebanon, 28th.

Meteor.—Selins Grove, 4th.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for March, 1894.

County.	Station.	Elevation above Sea Level (feet).	Temperature.								Precipitation.			Number of Days.			Wind. Prevailing Direction.	Observers.
			Mean.	Maximum.		Minimum.		Mean of Maximum.	Mean of Minimum.	Daily Range.		Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Clear.	Fair.	Cloudy.		
				Highest.	Date.	Lowest.	Date.			Mean.	Greatest.								
Allegheny,	Pittsburgh,	820	47·0	76	18, 20	15	27	57·9	37·0	20·9	38	2·41	3·1		9	14	8	NW	O. D. Stewart, W. B.
Berks,	Hamburg,	380	43·4	75	22	15	28	53·8	33·1	20·7	36	1·53			6	5	15	NW	William Shipe.
Berks,	Reading,*	280	42·0									1·32			9				Franklin Yager.
Blair,	Altoona,	1,181	49·4	73	22, 23	23	26, 30	58·5	40·2	18·3	27	·80			9				Dr. C. B. Dudley.
Blair,	Blue Knob,	2,500	40·8	65	22	11	28	48·9	32·8	16·1	30	2·49	2·5		7	7	11	NW	A. H. Boyle.
Blair,	Hollidaysburg (29 days),	947	43·3	75	22	13	21, 30	57·6	30·0	27·0	45	1·44	0·5		7	12	8	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	38·0	64	18	10	27	46·6	29·5	17·1	26	1·00	2·3		8	9	10	SW	G. W. T. Warburton
Bucks,	Forks of Neshaminy[1] (27 days),	300	44·2									1·70			11	12	8	W	J. C. Hillman.
Bucks,	Quakertown,	536	40·4	73	22	16	26	53·6	31·2	22·4	34	1·68			9		13	SW	J. L. Hescock.
Cambria,	Johnstown,	1,184	44·1	74	18	13	27, 28	56·5	32·4	24·1	43	1·95	1·0		9	14	9	NW	E. C. Lorentz.
Cameron,	Emporium,	1,050	40·8	73	18	11	28	53·5	28·2	25·3	44	1·24	3·2		8	8	16	SW	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	41·6	69	22	14	28	52·8	30·5	22·3	39	1·67	1·0		10	17	5	9	W	F. C. Wintermute.
Centre,	State College— Agricultural Experiment Sta.,	1,191	42·7	69	22	13	27	52·8	32·6	20·2	33	1·14	2·0		7	6	15	10	W	Prof. Wm. Frear.
Chester,	West Chester,	455	45·1	77	22	18	27	54·4	35·8	18·6	29	1·67			10	21	3	7	S	J. C. Green, D.D.S.
Chester,	Coatesville,	380	44·8	80	22	17	26,	56·9	32·6	24·3	39	2·08			8	19	5	7	W	W. T. Gordon.
Chester	Kennett Square,	275	45·4	80	22	17	28	56·7	34·0	22·7	37	1·45			12	15	8	8	NW	B. P. Kirk.
Chester,	Phœnixville,	190	45·3	78	22	16	27	55·5	35·1	20·4	36	1·76			11	10	11	10	NW	Knowles Croskey.
Chester,	Westtown,	350	43·7	77	22	18	27	53·2	34·2	19·0	35	1·60			10	18	9	10	W	John D. Carter.
Clearfield,	Grampian,	1,450	40·4	70	6, 18	10	27	50·0	30·8	19·2	36	2·27	3·0		7	5	17	9	W	Nathan Moore.
Clinton,	Lock Haven,	560	42·5	74	6, 18	13	28	56·3	28·7	27·6	44	·84			6	13	12	6	W	Prof. J. A. Robb.
Columbia,	Bloomsburg,—(27 days)																		
Crawford,	State Normal School, Meadville—	500	42·7	67	26	17	27	53·2	32·2	21·0	46	·31	1·5		3	13	7	7	NW	Prof. J. G. Cope.
	Divinity Hall,	1,200																	Prf. J. H. Montgomery.
Crawford,	Saegertown,	1,300	41·0	73	18	— 2	28	53·8	28·3	25·5	45	1·74	3·0		7	4	16	11	S	J. G. Appie.
Cumberland,	Carlisle,	480	43·2	78	22	15	1	54·4	32·2	22·3	36	1·14			7	20	7	4	S	J. E. Pague.
Cumberland,	Carlisle— Dickinson College,	480	43·6	76	22	15	1	54·5	32·6	21·9	37	·48			2	16	7	8	W	H. E. Smith.
Dauphin,	Harrisburg,	361	44·0	75	22	19	27	53·0	36·0	17·0	30	1·30			8	13	9	9	W	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College,	190	46·1	78	22	18	27	55·3	36·9	18·4	31	1·34			7	3	24	4	SW	Prof. S. J. Cunningham.
Erie,	Edinboro,*	1,400	39·7	68	18	13	27						10·0	2·0		17	7	7	S	C. F. Sweet.
Erie,	Erie,	681	41·0	75	18	17	26	49·0	33·0	16·0	36	1·95			14	8	16	7	S	P. Wood, W. B.
Fayette,	Uniontown,	1,000	45·8	76	20	16	27	56·0	35·5	20·5	37	2·90	2·0		10	12	16	3	SW	Wm. Hunt.
Franklin,	Chambersburg (30 days),	618	43·2	74	22	15	1	55·4	30·9	24·5	37	1·17			7	10	13	7	NW	J. C. Boggs.
Fulton,	McConnellsburg,	875																		T. F. Sloan.
Huntingdon,	Huntingdon— The Normal College,	650	44·0	75	22	14	28	57·8	30·1	27·7	44	1·07			5	16	5	10	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350																		Prof. S. C. Schmucker.
Juniata,	Kilmer,**	475	46·1	70	19	20	1					1·03			4	10	14	7	W	R. J. Mickey.
Lancaster,	Lancaster— Franklin and Marshall Col'ge,	413	44·8	78	22	17	1	55·7	33·8	21·9	35	1·49			5	15	10	6	W	W. E. Bushong.
Lawrence,	New Castle,	932	42·8	75	18	13	27	55·2	30·4	24·8	45	1·47	1·2		5	11	11	9	W	Wm. T. Butz.
Lebanon,	Lebanon,	458	43·6	70	22	17	28	53·7	33·4	20·3	34	1·48			9	15	8	8	W	G. W. Hayes, C.E.
Lehigh,	Coopersburg,	520	43·8	72	22	18	27	53·6	33·9	19·7	33	1·60			11	14	10	7	SE	Dr. M. H. Boye.
Luzerne,	Drifton,	1,683																		J. R. Wagner.
Luzerne,	Wilkes-Barre,	575	43·6	70	6	16	27	55·6	31·0	23·6	40	1·68	2·0		8	13	9	9	W	A. W. Betterly.
McKean,	Kane,	2,000	39·6	72	18	9	27	49·8	29·4	20·4	32	2·24	6·0		9	11	8	12	SE	C. H. Kemp.
McKean,	Smethport,	1,500	39·0	75	18	7	28	50·8	27·2	23·6	46	1·86	5·0		8		20	11	SE	Armstrong & Brownell.
Mercer,	Greenville— Thiel College,	1,000	43·0	77	18	12	27	54·4	31·5	22·9	43	1·94	2·0		6	19	9	10	S	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	45·4	80	22	20	1, 27	55·7	35·1	20·6	35	1·74			8	21	3	7	W	Charles Moore, D.D.S
Montgomery,	Skippack,																			B. W. Dambly.
Northampton,	Easton— Lafayette College,	325	42·4	69	22	16	27	51·3	33·6	17·7	31	1·25			9	11	11	9		J. W. Moore.
Perry,	(Aqueduct) Logania,	367	46·0	84	22	15	27, 28	56·0	35·9	20·1	35	1·09			7	18	5	8	NW	Richard Callin.
Philadelphia,	U. S. Weather Bureau,	117	47·0	77	22	21	27	55·8	38·3	17·5	29	1·45			10	12	8	11	NW	L. M. Dey, W. B
Philadelphia,	1529 Centennial Avenue,	120	47·3	80	22	21	27	56·4	38·2	18·2	31	1·64			11	12	11	8	NW	John Comly.
Philadelphia,	3211 Locust Street,	100	45·9	77	22	21	27	54·6	37·2	17·4	30	1·70			13	13	11	7	NE	R. L. Padock.
Pike,	Blooming Grove,*		39·6	67	18	17	27					1·11			5	5	16	10	S	John Grathwohl,
Potter,	Shingle House,	1,475	38·8	72	18	11	27, 28	50·8	26·8	24·0	43	1·84	6·2		9	6	15	10	NW	C. D. Voorhees, M.D.
Schuylkill,	Girardville,	1,000																		E. C. Wagner.
Snyder,	Selins Grove,	455	42·6	74	22	16	27	54·5	30·8	23·7	37	1·09			2	29		2	SW	J. M. Boyer,
Somerset,	Somerset,	2,250	43·6	74	18	8	27	54·1	33·2	20·9	36	1·85	3·5		7	5	18	8	SW	W. M. Schrock.
Tioga,	Wellsboro,*	1,327	38·3	72	18	10	27					·24	2·0		2	7	12	12	S	H. D. Deming
Union,	Lewisburg,	450	44·5	68	22	16	27	54·2	30·8	23·4	36	1·13	1·5		6	9	8	17	W	Prof. W. G. Owens.
Wayne,	Dyberry,	1,100	37·7	66	18	11	27	49·0	26·4	22·6	43	1·55	2·5		6	10	8	13	W	Theodore Dav.
Wayne,	Honesdale,	1,000	37·5	64	19	12	27	47·4	27·6	19·8	34	1·59	1·2		10	13	8	10	NW	John Torrey †
Wayne,	(Salem Corners) Hamlinton,	1,600	39·6	66	5, 19	14	26	48·2	31·0	17·2	30	1·73	2·5		11	13	5	13	W	T. B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	45·0	77	22	11	27	53·0	37·1	15·9	30	2·31								Murray Forbes.
Westmoreland,	Ligonier,	1,750	42·8	78	18	4	27	56·9	28·8	28·1	48	2·29	2·0		8	14	10	7		C. D. Ambrose.
Wyoming,	South Eaton,	660	41·2	67	6, 19	14	27	51·4	31·0	20·4	36	·80			7	10	12	9	NW	B. M. Hall.
York,	York,	385	45·1	80	22	16	1	56·2	34·0	22·2	36	1·58			10	15	9	7	NW	Mrs. L. H. Grenewald.

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, 7+2+9+9+4. [2] Mean temperature 8+8+9 † Died March 9.

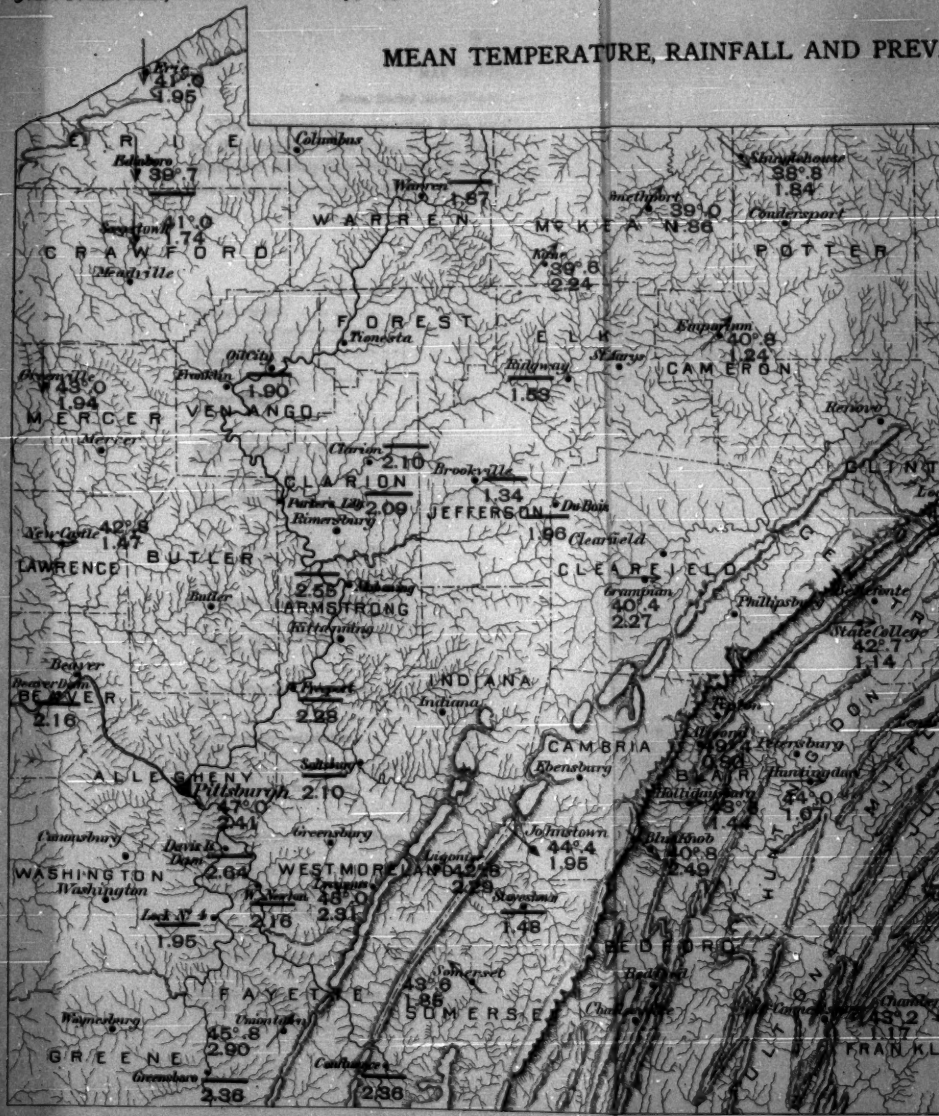
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Blooming Grove,		.07						.01							.22								.72		.09							1.11
Browers Lock,										.16					.16	.07			.03		.24	.45	.52		.04				.24			2.03
Coatesville,									.11		.02				.29				.05		.31	.48	.55		.05				.28			2.08
Coopersburg,						.01			.03	.01				.14	.13				.02		.18	.22	.43		.09				.28			1.60
Doylestown,					.15				.08						.16	.02					.25	.28	.27		.08				.09			1.38
Dyberry,									.01						.32						.09	.25	.79						.09			1.55
Easton,										.01						.19			.13		.02	.15	.47		.13	.02			.20			1.25
Forks of Neshaminy,						.05			.07			.13	.04		.20				.02		.27	.20	.40		.20				.22			1.70
Frederick,									.06				.03		.17				.03		.26	.20	.44		.08				.22			1.49
Hamburg,												.22			.24				.11			.10	.62						.24			1.53
Honesdale,									.04			.02			.24				.04		.02	.42	.71		.02	.02			.06			1.59
Kennett Square,						.08			.08	.03	.02		.01		.05	.09					.18	.08	.70		.03				.10			1.45
Lansdale,						.02			.13		.03				.24						.23	.26	.49		.04				.30			1.74
Mauch Chunk,		.05					.03						.02		.22				.09		.02	.21	.81		.02				.20			1.67
Ottsville,									.06				.04		.18				.04			.39	.51		.12				.22			1.56
Philadelphia, a†							.03			.04	.03				.04	.13					.25	.19	.54		.03				.17			1.45
Philadelphia, b,							.03		.01	.08	.03		.01		.06	.17					.15	.24	.62		.05				.20			1.64
Philadelphia, c,							.05		.01	.06	.04		.02		.06	.15			.01		.20	.25	.59		.05				.21			1.70
Phœnixville,		.01					.01		.16		.02				.12				.06		.17	.41	.49		.06				.25			1.76
Point Pleasant,						.03									.20				.07		.14	.37	.23	.13	.02				.20			1.39
Pottstown,												.12			.15				.04		.22	.30	.58		.07				.26			1.74
Quakertown,							.03			.06			.03		.22				.10		.20		.71		.12				.21			1.68
Reading,							.02		.01						.15				.01		.25	.15	.43		.05				.25			1.32
Salem Corners,		.12						.19							.18				.03	.13		.03	.80		.08	.02	.05		.07			1.73
Seisholtzville,															.22				.05			.15	.45		.07				.24			1.40
Skippack,																																
Smith's Corner,						.05			.03	.03	.03		.01		.12	.06			.04		.17	.40	.29		.15	.03			.25			1.71
Swarthmore,					.28						.05		.05			.01					.30		.70						.15			1.34
West Chester,						.03		.14		.03				.15	.02						.25	.24	.65		.02				.14			1.67
Westtown,						.06		.10	.02						.10	.10					.30	.25	.46		.01				.20			1.60
Susquehanna Basin.																																.80
Altoona,															.27	.10			.04	.07			.32									
Aqueduct,							.03								.25				.15		.11	.14	.36						.05			1.09
Bloomsburg,													.03		.15				.15			*	*	*								.31
Blue Knob,						.09									.61				.31		.23		1.00			.10	.15					2.49
Carlisle,							.02								.22				.06		.14	.18			.22				.30			1.14
Drifton,				*						*					.15	.10		*							*				.10			.35
Emporium,						.03	.10								.20				.19		.05	.30	.19						.25			1.24
Gettysburg,														.06		.13						.11	.60	.08					.23			1.91
Girardville,																																
Grampian,							.15								.44				.14		.55	.24	.60						.15			2.27
Harrisburg,†						.08									.18	.03			.07		.07	.30	.44						.23			1.30
Hollidaysburg,															.62	.03			.09		.10	.31	.22	*					.05			1.44
Huntingdon,															.50				.16		.03	.18	.20									1.07
Kilmer,						.05									.33							.09	.36									1.03
Lancaster,															.40						.21	.23	.30						.45			1.49
Lebanon,							.03							.06	.28				.05		.15	.20	.59		.02				.16			1.48
Le Roy,							.04		.02						.15							.28	.43		.03	.02	.03					1.00
Lewisburg,							.05								.15	.30			.07			.22	.34									1.13
Lock Haven,						.02									.20				.13		.01	.40	.08									.84
Selins Grove,																						.35	.74									1.09
South Eaton,														.02	.20				.05			.16	.33		.03	.01						.80
State College,							.07						.07		.38				.16		.11	.21	.80									1.24
Wellsboro,															.20							.04										.24
Wilkes-Barre,		.02					.03								.26				.10			.04	1.00		.11				.12			1.68
York,							.04			.02			.01		.11				.04		.16	.13	.61		.14				.32			1.58

†U. S. Weather Bureau Stations. *Missing.

URING MARCH, 1894.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,						.26										.57			.03	.16	.02	.24	.70			.12			.04	.02		2.16
Brookville,							.12									.14			.12			.08	.73						.13	.02		1.34
Clarion,							.49							.01		.29				.06		.20	.80				.06	.01	.15	.03		2.10
Confluence,							.11									.70			.06	.25	.06	.30	.67	.06		.15						2.36
Davis Island Dam,							.35									.65			.06	.22	.08	.01	.79			.35	.08		.05			2.04
DuBois,							.19								.52							.19	.77						.09			1.96
Elwood Junction,							.31									.40				.14		.04	.78			.11	.06			.05		1.89
Freeport,							.29									.63			.03	.23	.03	.19	.82						.13			2.28
Greensboro,							.15									.65			.08	.20	.05	.45	.67	.02		.06				.03		2.36
Greenville,						.34	.02								.46				.09		.10	.47	.42					.04				1.94
Immel Reservoir,							.18								.60				.39		.25	.20	.63			.06						2.31
Indiana,																																
Johnstown,						.05	.03									.72			.21		.23	.34	.43				.03	.01				1.95
Kane,						.20	.15								.20				.08		.37	.42				.10		.30				2.24
Ligonier,						.11									.65				.30	.14		.60	.28		.01	.20						2.99
Lock No. 4,							.18					.01				.62			.14	.13	.02	.06	.77			.01	.01					1.95
Mahoning,							.30									.55			.02	.10	.03	.35	.92				.03		.21	.04		2.55
Meadville,																																
New Castle,							.32							.39					.13				.48			.15						1.47
Oil City,							.31									.48				.08	.02	.10	.68				.08		.15				1.90
Parker's Landing,							.40									.48				.11	.02	.24	.79				.01		.10	.01			2.09
Pittsburg,†						.12	.04								.68				.38		.12	.38	.33			.31			.05			2.41
Ridgway,							.21									.18			.08			.24		.62			.01		.19			1.53
Saegerstown,							.06								.10								.60	.28			.30	.10	.10			1.74
Saltsburg,							.17									.66			.06	.12	.06	.05	.80	.02		.02	.03	.01	.07	.03		2.10
Shingle House,							.13								.30				.03		.13	.39	.40			.22	.07		.17			1.84
Smethport,							.15								.20			.30			.25	.33	.33				.10		.20			1.86
Somerset,							.15						.20		.25				.80		.15		.45			.45						1.85
Stoyestown,																.69			.08	.04	.13	.08	.03			.20	.30					1.48
Uniontown,							.21								.70				.45		.58	.46	.39			.02	.03	.04		.02			2.00
Warren,							.30									.21						.27	.85				.11	.10	.02	.01			1.87
West Newton,							.34									.57			.10	.20	.04	.09	.78			.10							2.16
Potomac Basin.																																
Chamberburg,							.01						.05		.28				.08		.09		.44						.22			1.17
McConnellsburg,																																
Lake Basin.																																
Erie,†							.03	.11								.12			.01	.14	.06	.59	.37	.01	.01	.13	.01	.03	.13			1.95

MEAN TEMPERATURE, RAINFALL AND PREV



EVAILING WIND DIRECTION FOR MARCH. 1894

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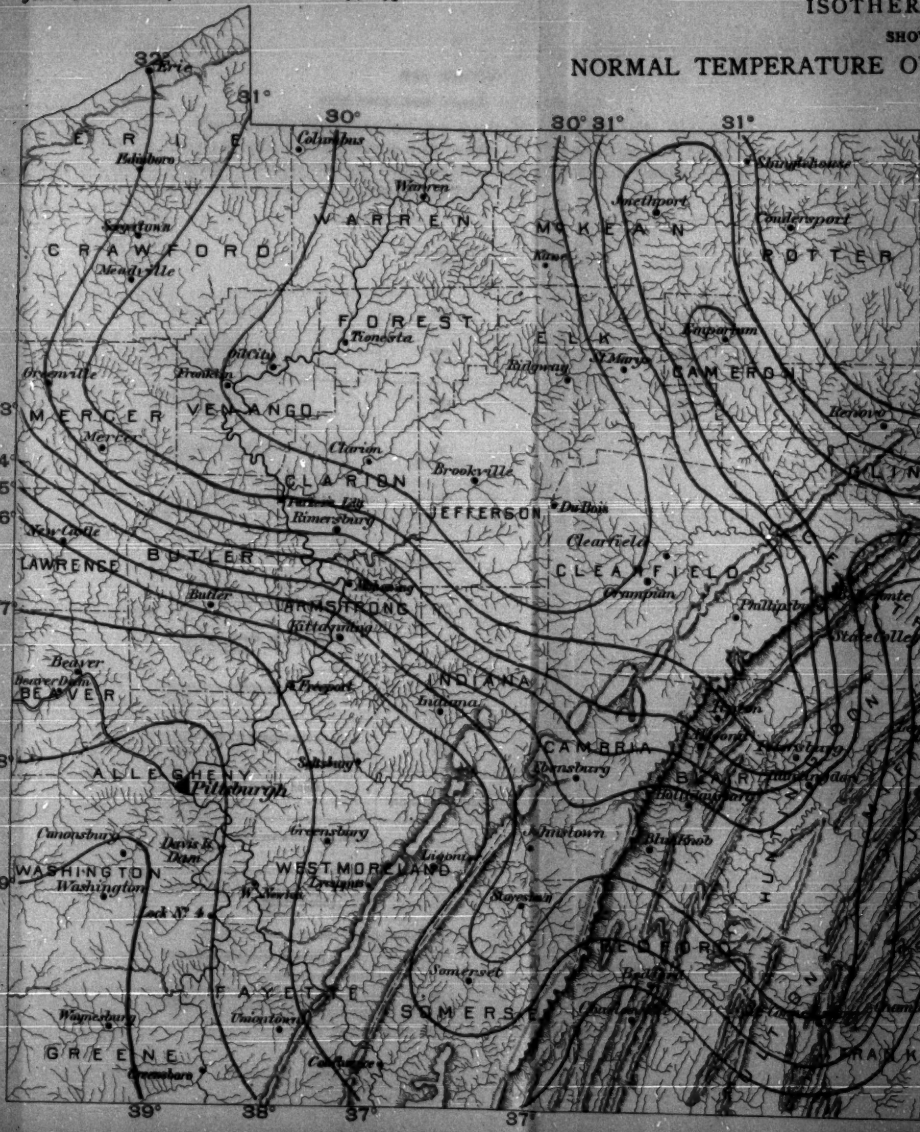
NORMAL TEMPERATURE O



State Weather Service.

ERMAL LINES,

HOWING THE

OF PENNSYLVANIA FOR MARCH.

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MAY WEATHER.

From United States Weather Bureau Records.

The following data, compiled from the records of observations taken during the length of time given at each station, show the average and extreme conditions during that time, and also the range within which weather variations may be expected to keep in any future May.

	Philadelphia. (23 years.)	Pittsburgh. (23 years.)	Erie. (20 years.)
Mean or normal,	62°	62°	56°
Warmest May,	1880	1880	1880
Average,	69°	69°	65°
Coldest May,	1882	1882	1882
Average,	57°	57°	51°
Highest temperature recorded,	96°	93°	91°
Date,	26th, 1880	3d, 1887	30th, 1879
Lowest temperature recorded,	36°	27°	31°
Date,	1st, 1880; 6th, 1891	1st, 1876	3d, 1885
Average date of last "killing" frost (spring),	April 9th	April 27th	April 30th
Average precipitation (inches),	3·01	3·45	3·86
Average number of days with ·01 inch or more,	12	14	13
Greatest monthly precipitation,	5·83	6·45	8·05
Date,	1873	1889	1892
Least monthly precipitation,	0·34	0·98	1·04
Date,	1880	1871	1879
Greatest amount in 24 hours,	1·89	2·96	4·71
Date,	7th and 8th, 1886	10th and 11th, 1889	16th and 17th, 1893
Greatest amount snowfall in 24 hours,	0	Trace	2·00
Date,		3d, 1885	9th, 1885
Average number clear days,	9	8	10
Partly cloudy,	12	13	12
Cloudy,	10	10	9
Prevailing direction of wind,	SW	NW	W
Highest velocity, miles per hour,	60	36	60
Date,	10th, 1889	9th and 12th, 1875	1875